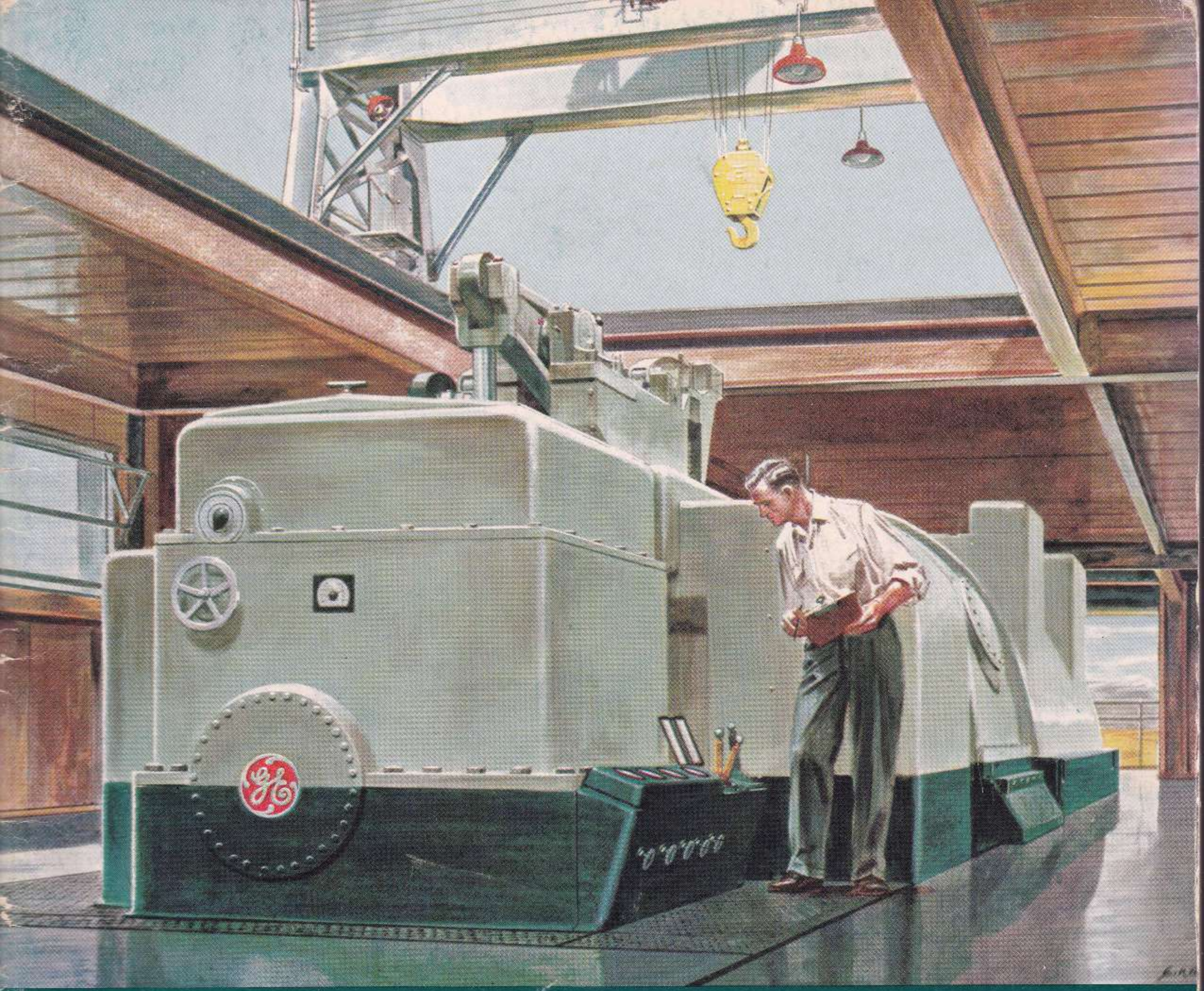
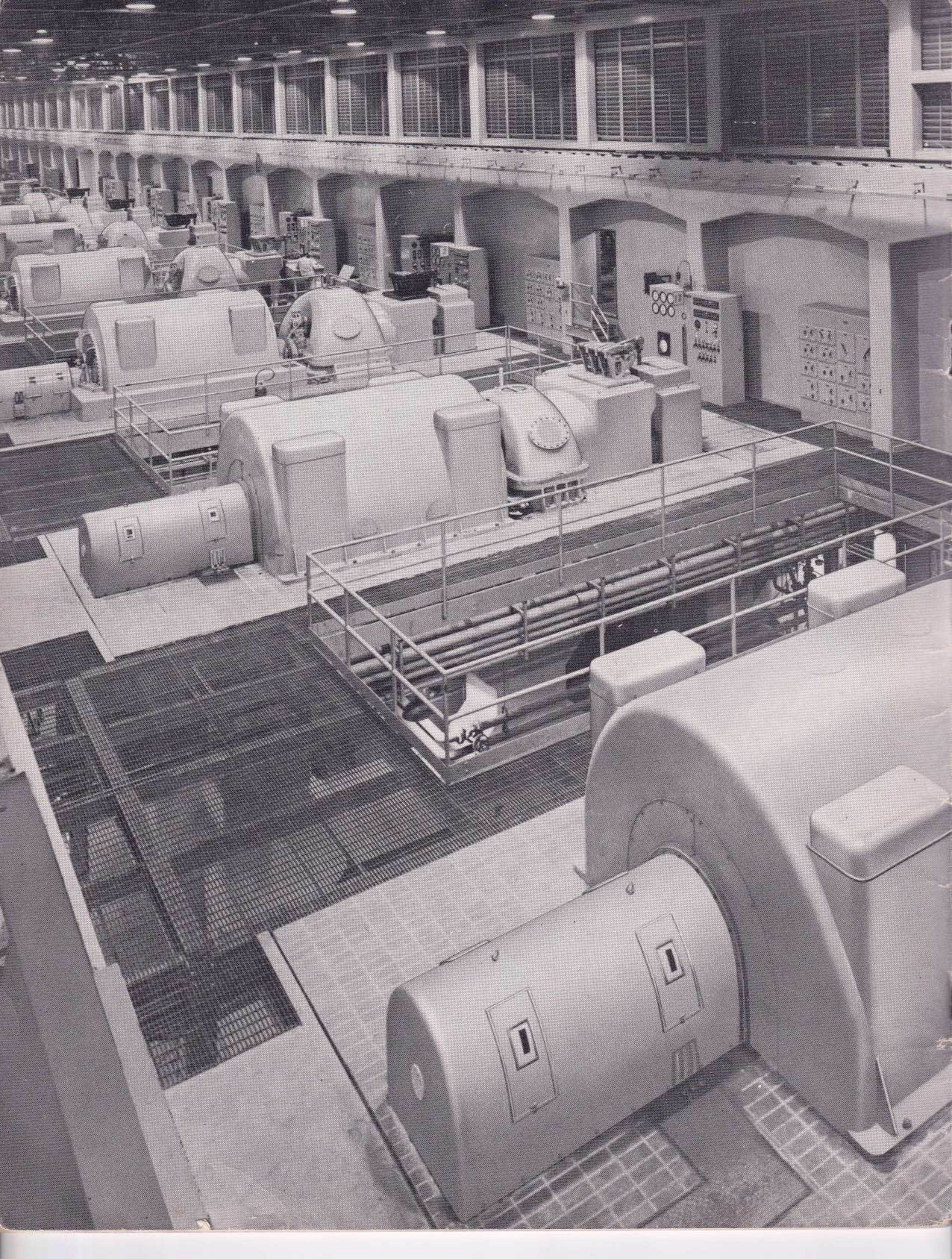


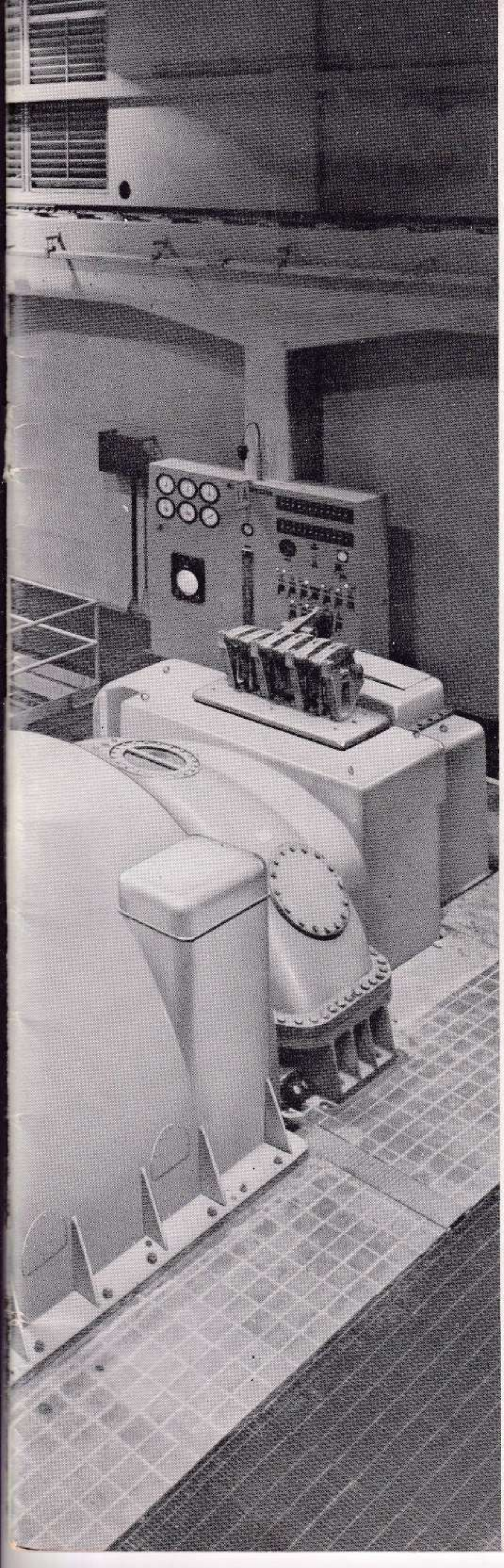
TURBINE-GENERATORS

2500 KW TO 40,000 KW

FOR ELECTRIC UTILITIES AND INDUSTRIAL PLANTS
CONDENSING AND NONCONDENSING APPLICATIONS

GENERAL ELECTRIC





GENERAL ELECTRIC TURBINE-GENERATORS

2,500 TO 40,000 KILOWATTS

Since developing the impulse-type turbine in 1902, the General Electric Company has designed, built, and placed in service over 63,000,000 kilowatts in turbine-generators, and more than 45,000,000 horsepower in turbines for ship propulsion and mechanical-drive applications.

In many of these installations General Electric pioneered with its customers the application of new engineering developments, new product features, and new manufacturing techniques which have resulted in the high efficiency of today's turbines and generators. This ever-increasing efficiency has helped electric utilities produce electric power at constantly decreasing costs, and enabled industrial firms to enjoy greater economy where turbines are coordinated with plant processes.

Most of the turbine-generators described in this bulletin represent new designs which are the result of close co-ordination of research, engineering, and experienced manufacturing.

FLEXIBLE DESIGN

The extreme flexibility of G-E turbine design permits the successful application of turbines to an almost unlimited variety of operating conditions; this means that you can get a turbine to meet your precise requirements.

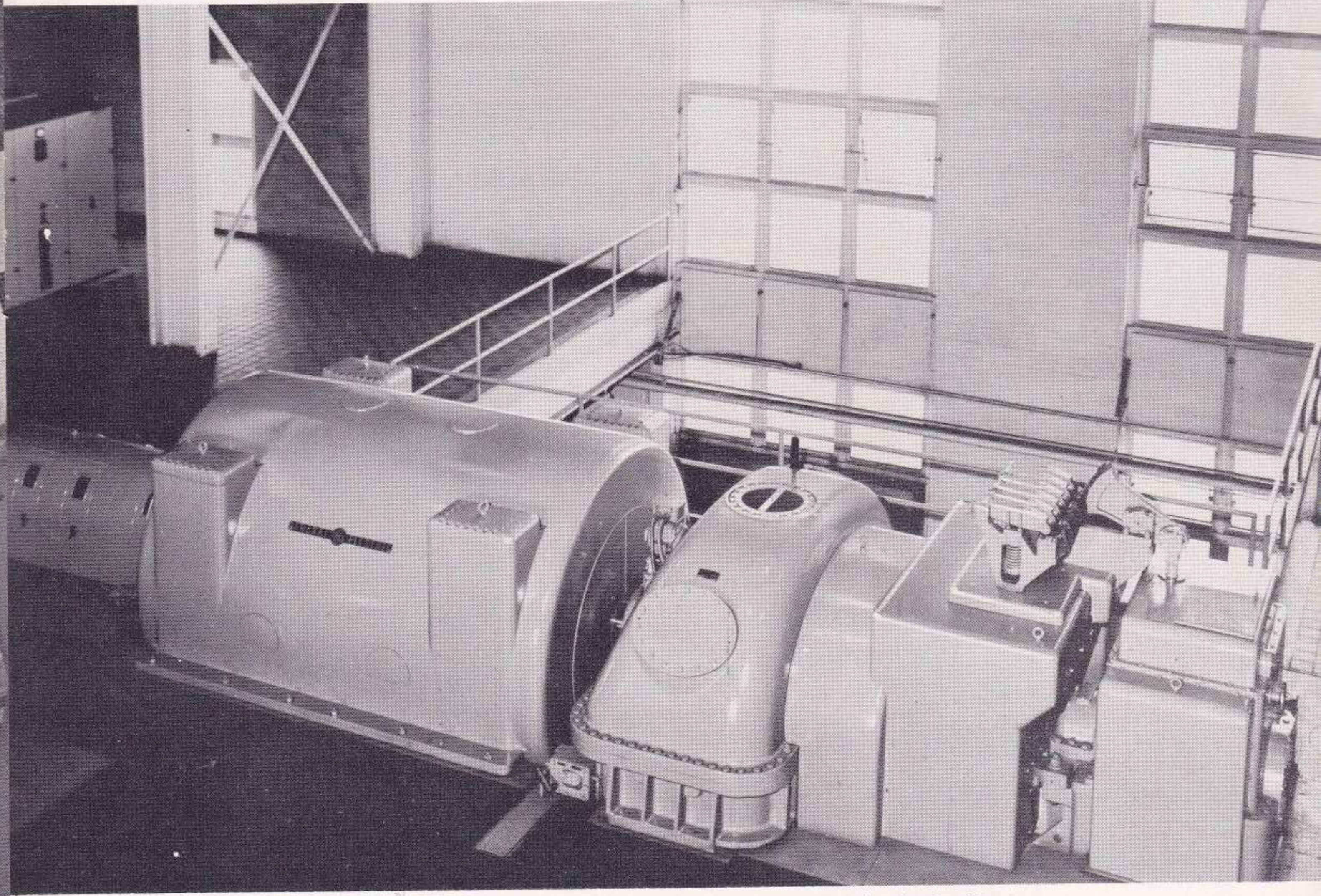
The turbine types vary from those designed for straight condensing or non-condensing operation, to those arranged for both extraction of steam for process work and the admission of steam from low-pressure sources.

CUSTOM BUILT

Each unit is custom-built to meet your particular application requirements and to operate under your steam conditions, giving greatest economy in fuel consumption relative to power output.

In selecting turbine-generators, it is desirable to take advantage of the experience of General Electric application engineers, who will gladly work with you to determine the correct turbine for the job, and help you get more for your turbine dollar with General Electric turbines.

Line-up of General Electric turbine-generators producing power for pot-lines in an aluminum plant.



General Electric steam turbine-generator producing power for electric utility.

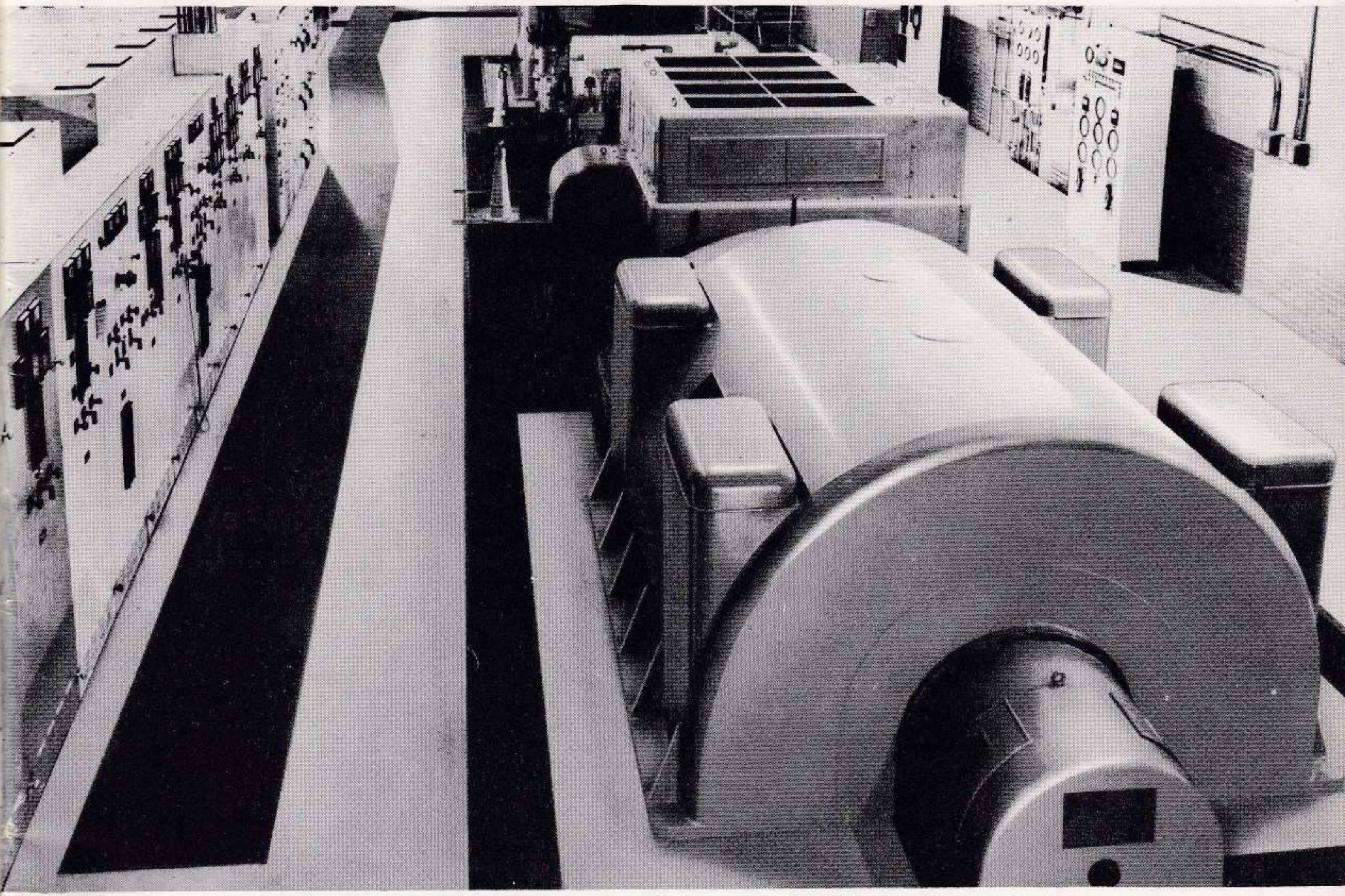
Utility and Industrial Applications

INDUSTRIAL APPLICATIONS

Manufacturing and processing industries that can economically generate their own electric power have long consulted with General Electric on turbine-generator applications.

General Electric pioneered in the development of single, double, and triple-automatic extraction turbines to meet the complicated factors involved in plant heat balance. Highly accurate governing systems have been engineered to handle widely fluctuating demands for both electric power and process steam. Compact designs have been built to provide ease of installation in existing plant facilities.

In these areas, and many more, General Electric turbine designers are advancing the art of industrial power generation. They are supplemented by engineers in the field who are ready to adapt these developments to your particular needs.



General Electric triple-automatic-extraction turbine-generator producing power and furnishing extraction steam for plant process uses.

G-E Turbines are Available to Meet A Wide Variety of Applications

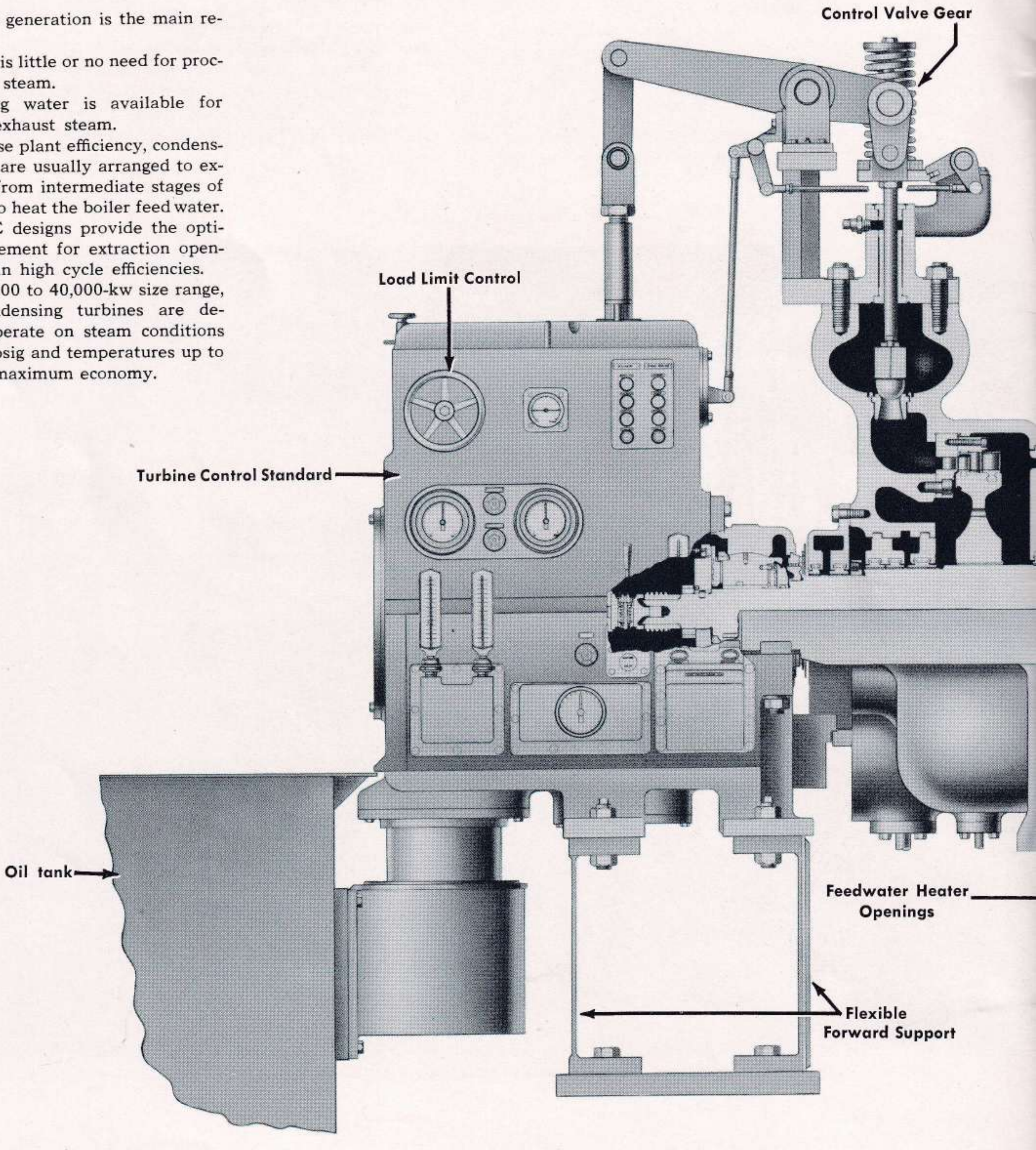
STRAIGHT CONDENSING

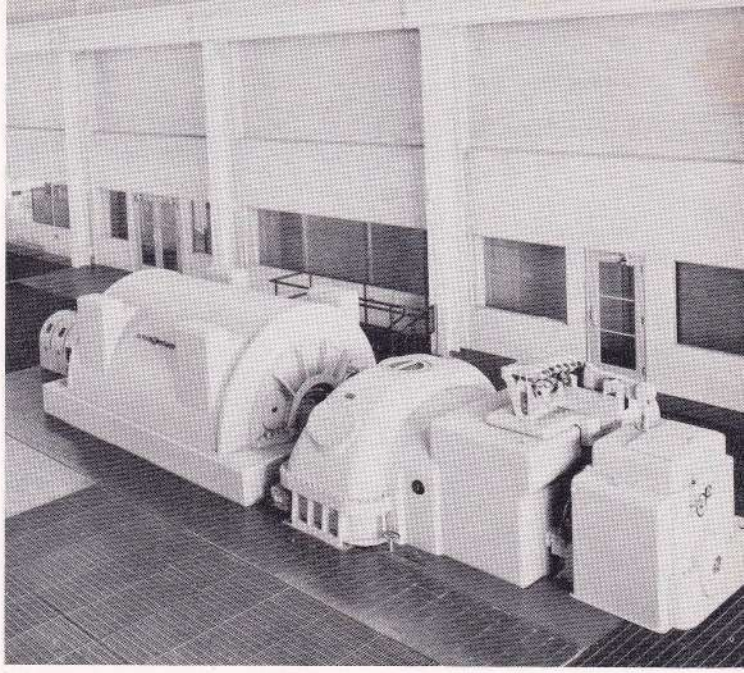
A straight condensing steam turbine is usually applicable when these conditions exist:

1. Power generation is the main requirement.
2. There is little or no need for process pressure steam.
3. Cooling water is available for condensing exhaust steam.

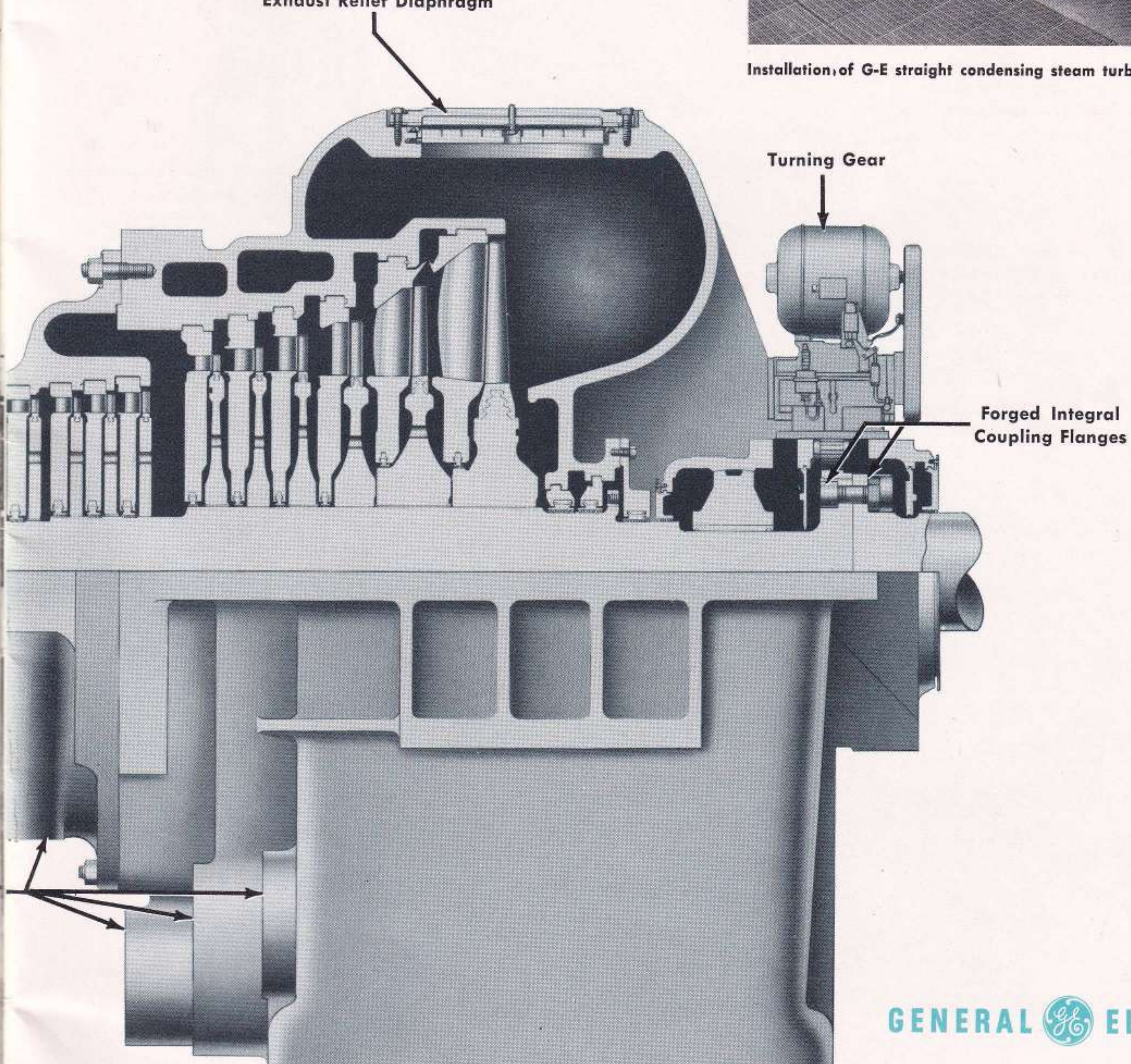
To increase plant efficiency, condensing turbines are usually arranged to extract steam from intermediate stages of the turbine to heat the boiler feed water. Flexible G-E designs provide the optimum arrangement for extraction openings to obtain high cycle efficiencies.

In the 2,500 to 40,000-kw size range, straight condensing turbines are designed to operate on steam conditions up to 1450 psig and temperatures up to 1050 F for maximum economy.





Installation of G-E straight condensing steam turbine-generator.



Sectional view of General Electric straight condensing steam turbine.

GENERAL ELECTRIC

CONDENSING DOUBLE FLOW

The condensing double flow exhaust is used with larger turbine-generators to provide greater efficiency. This unit handles the large steam flow by splitting it into two parts. This is the most economical arrangement for producing low cost power.

Such features as the following help assure the efficiency and long life of G-E turbines:

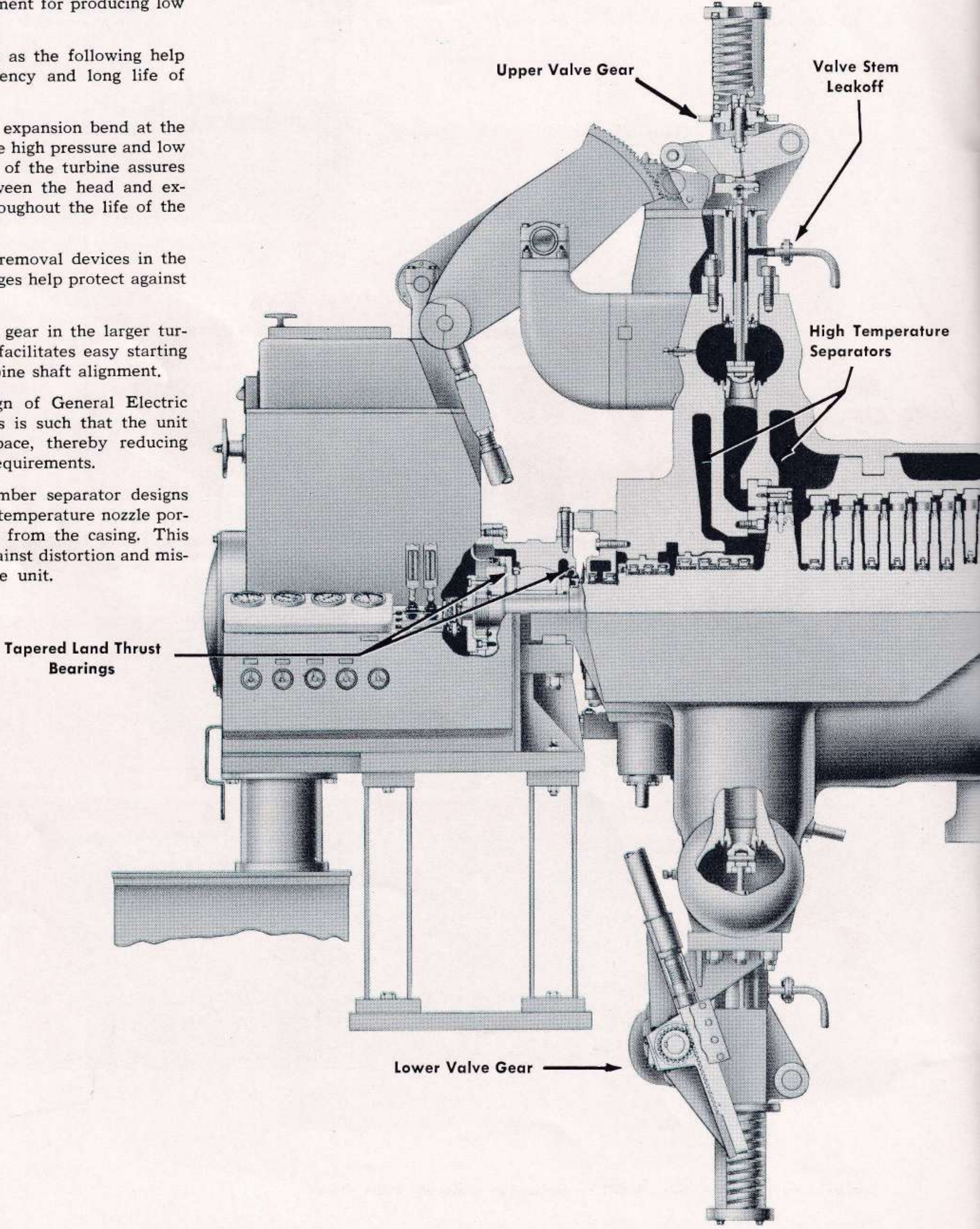
1. A flexible expansion bend at the joint between the high pressure and low pressure section of the turbine assures tight joints between the head and exhaust casing throughout the life of the machine.

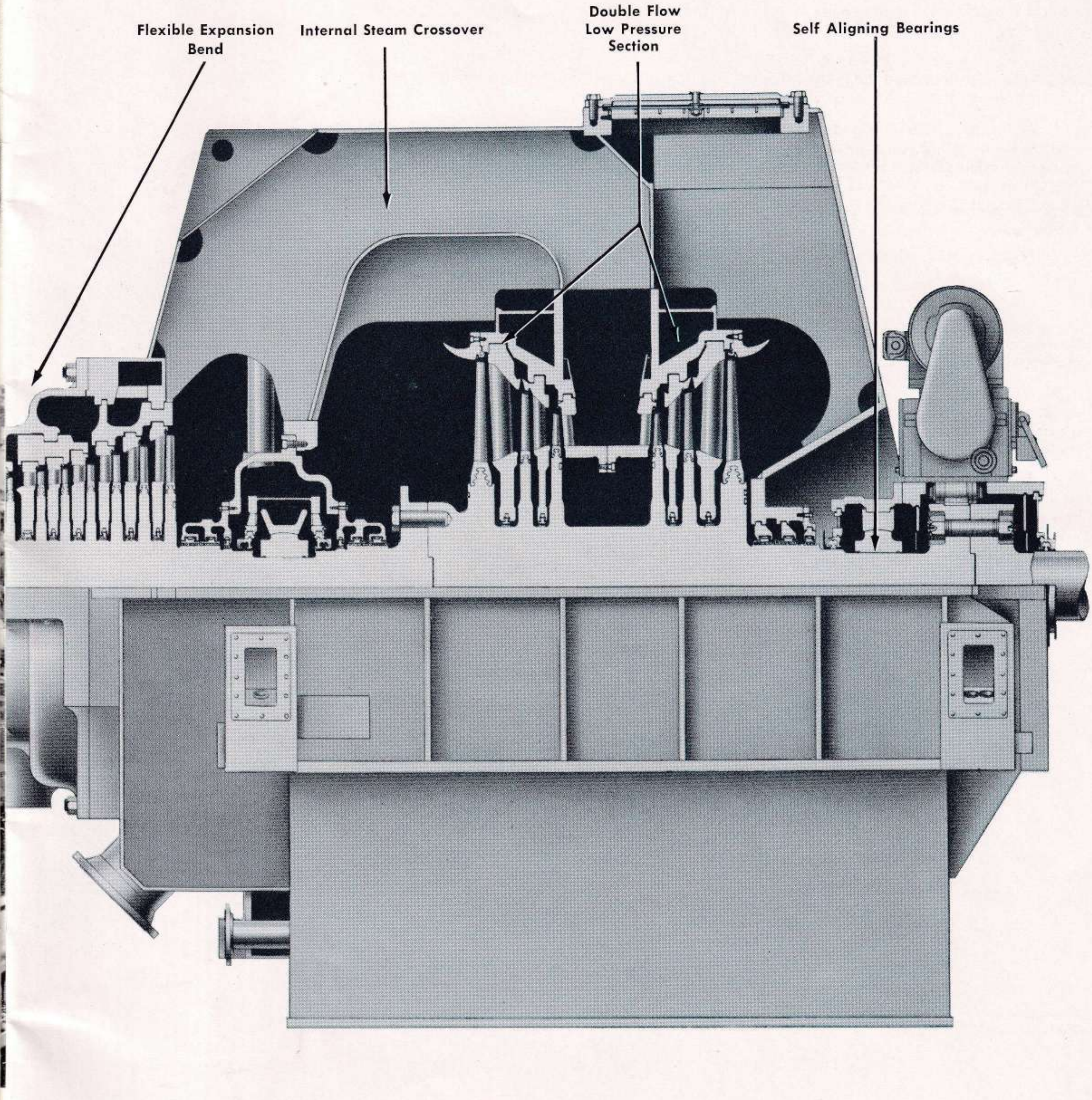
2. Moisture removal devices in the low pressure stages help protect against erosion.

3. A turning gear in the larger turbine-generators facilitates easy starting and assures turbine shaft alignment.

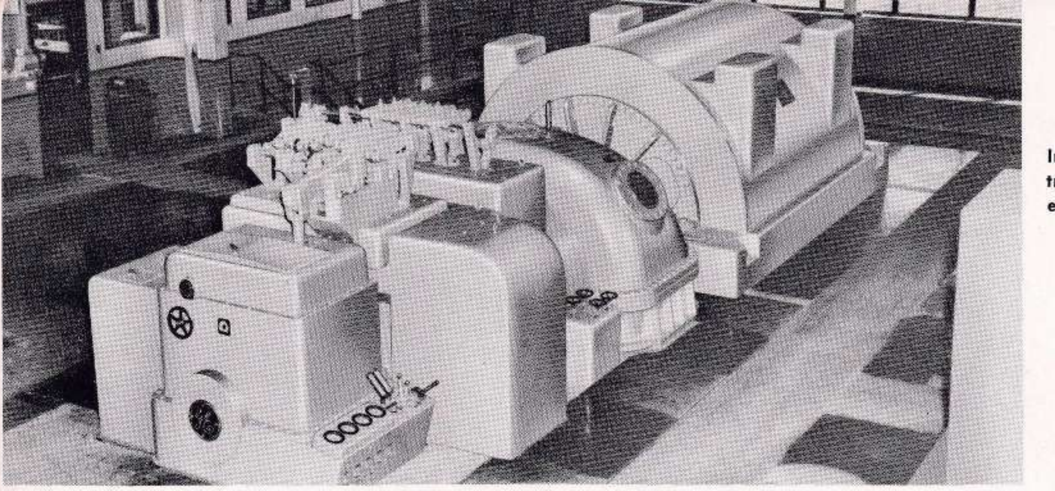
4. The design of General Electric impulse turbines is such that the unit requires less space, thereby reducing station space requirements.

5. Heat chamber separator designs isolate the high-temperature nozzle portion of the unit from the casing. This helps protect against distortion and misalignment of the unit.





Sectional view of General Electric 40,000-kw double flow condensing steam turbine.



Installation of General Electric single-automatic-extraction, condensing steam turbine-generator in an electric utility.

SINGLE AUTOMATIC EXTRACTION CONDENSING

Single-automatic-extraction, condensing steam turbines are applied where:

1. Large and variable amounts of process steam are required and

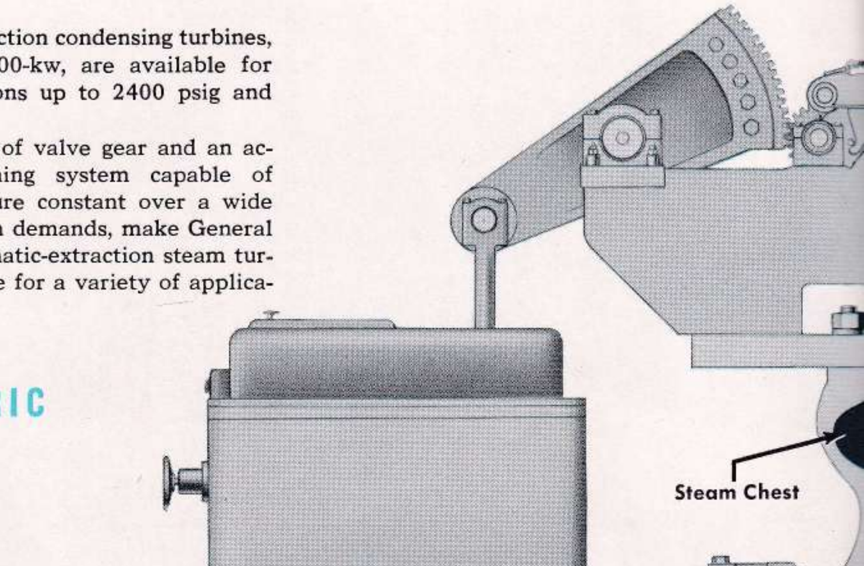
2. where cooling water is available for condensing exhaust steam.

Even when the load on the unit fluctuates and the flow of extracted steam varies, the pressure of extracted steam is automatically held constant. Desired pressure of extracted steam can be set, and the turbine automatically holds that pressure.

Single extraction condensing turbines, 2,500 to 40,000-kw, are available for steam conditions up to 2400 psig and 1050 F.

Five types of valve gear and an accurate governing system capable of holding pressure constant over a wide range of steam demands, make General Electric automatic-extraction steam turbines available for a variety of applications.

GENERAL ELECTRIC



Sectional view of General Electric double-automatic-extraction, condensing steam turbine.

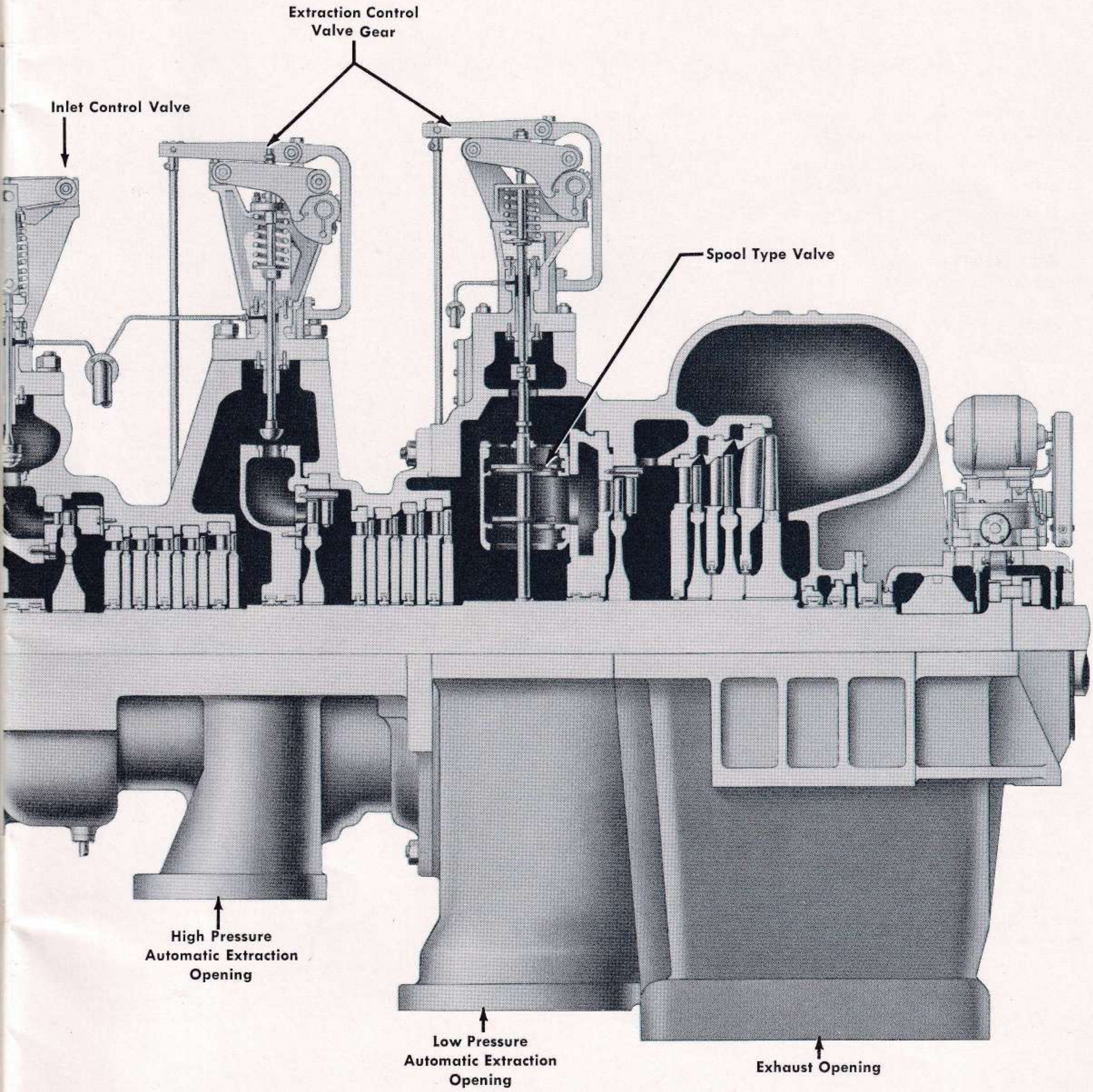
DOUBLE AUTOMATIC EXTRACTION CONDENSING

Double-automatic-extraction, condensing steam turbines are applicable where:

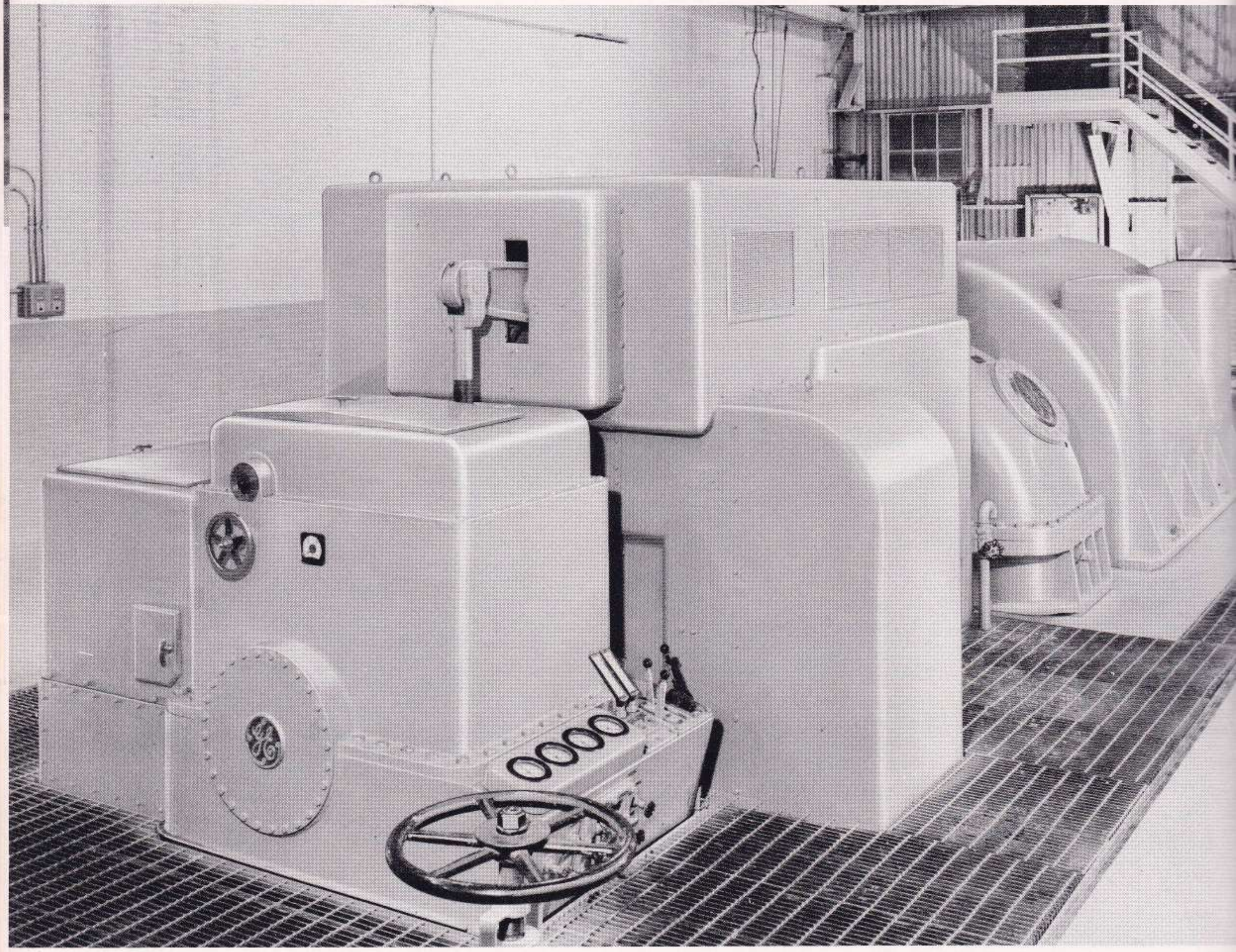
1. Extracted steam, at two different pressures, is needed for your industrial processes.
2. Where cooling water is available to condense exhaust steam.
3. Where electrical loads vary.
4. Where there is wide variation in the quantity of steam required.

General Electric's extraction governor is capable of holding extracted pressures extremely accurately, even when process requirements vary either together or independently, and when the electrical load varies.

G.E.'s automatic-extraction-turbines are in use in a great number of industries, such as paper, textile, chemical, petroleum, lumber, steel, food and wherever process steam requirements are high.


Extraction Control Valve Gear
Inlet Control Valve
Spool Type Valve
High Pressure Automatic Extraction Opening
Low Pressure Automatic Extraction Opening
Exhaust Opening

TRIPLE AUTOMATIC EXTRACTION CONDENSING



First triple-automatic-extraction steam turbine-generator was built by General Electric. This unit furnishes extraction steam for process use at three different pressures.

Triple-automatic-extraction condensing, turbines are used where:

1. Process steam is required at three different pressures or any combination of four total steam pressure levels.
2. Cooling water is available to condense exhaust steam.
3. Electric load varies.
4. Process steam requirements vary widely.

A turbine of this type is particularly valuable when there is an expansion of an existing plant, requiring more electric capacity and an increase of three process steam flows. The use of this turbine and one boiler satisfies all these demands.

This unique General Electric unit can be used to maintain a steam balance over almost any variety of operating conditions. In addition, these extraction openings can be used as admission openings where required.

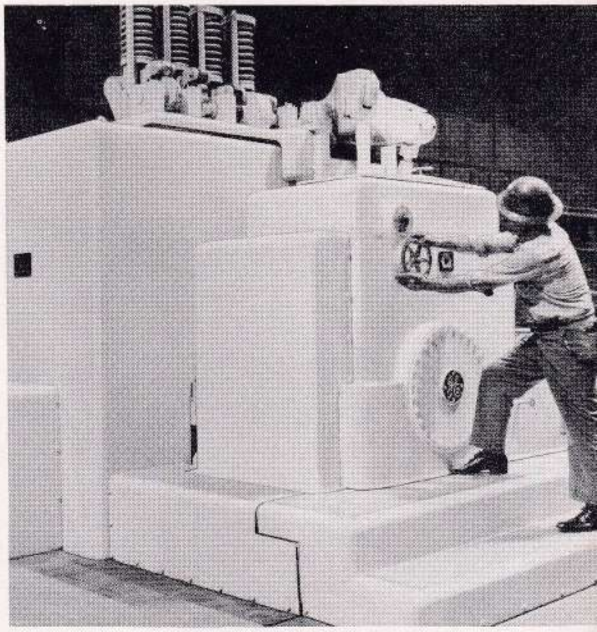
STRAIGHT NONCONDENSING

Straight noncondensing steam turbines are often applied when:

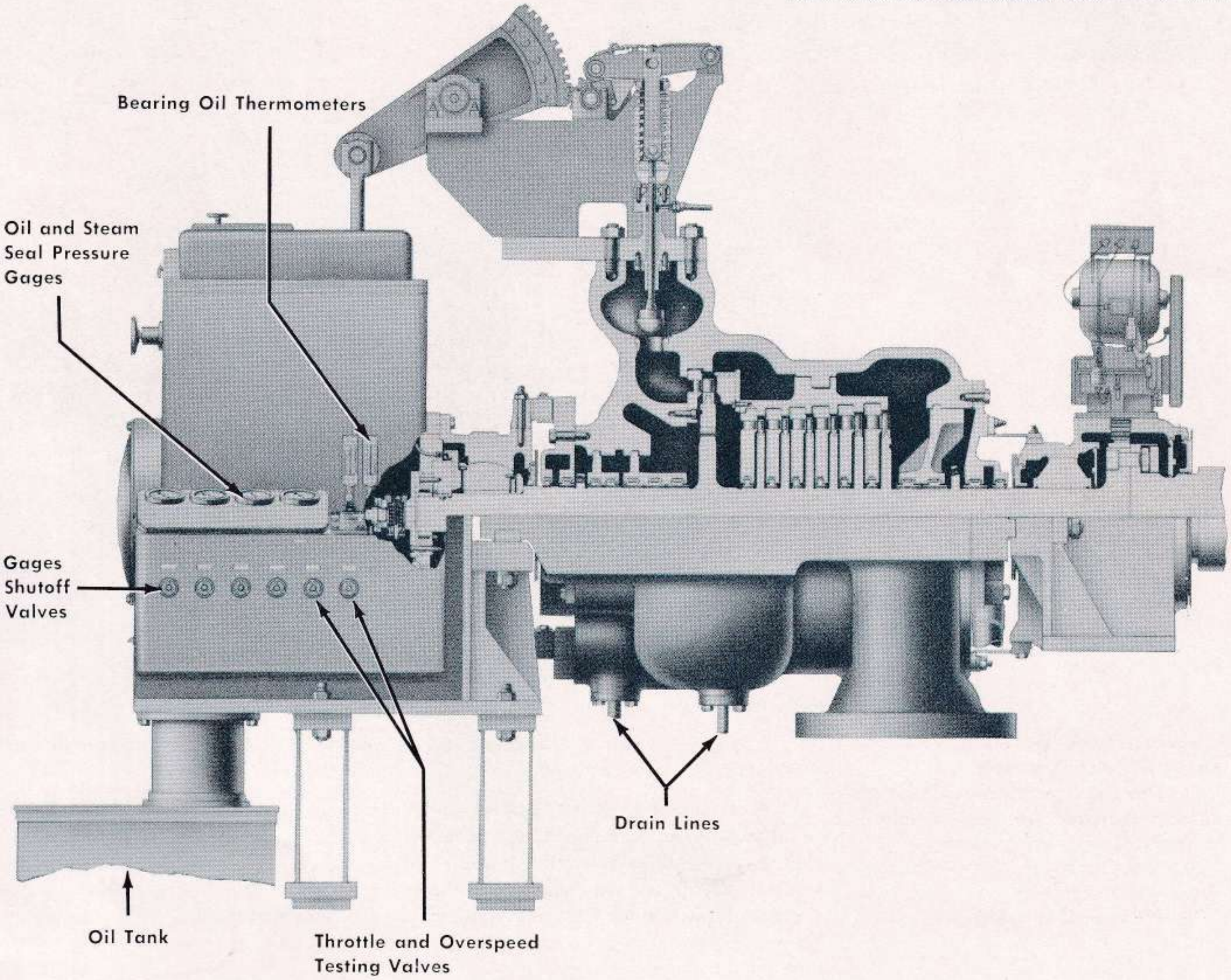
1. There is a demand for large quantities of lower-pressure steam at one pressure for process or other uses, and
2. where the unit can be operated in parallel with other units which can absorb load variation.

A noncondensing turbine is in the majority of cases controlled by a pressure governor which maintains the desired pressure of the process steam exhausted from the turbine by automatically adjusting the load on the unit. If demands for process steam fall off without a corresponding reduction in total plant load, it is necessary that part of the load be carried by other units.

Noncondensing turbines are also installed in topping arrangements exhausting to existing generating equipment to increase over-all plant efficiency and output.



Installation of General Electric straight noncondensing steam turbine-generator in a steel plant.


Bearing Oil Thermometers
Oil and Steam Seal Pressure Gages
Gages Shutoff Valves
Oil Tank
Throttle and Overspeed Testing Valves
Drain Lines

Sectional view of General Electric straight noncondensing steam turbine.

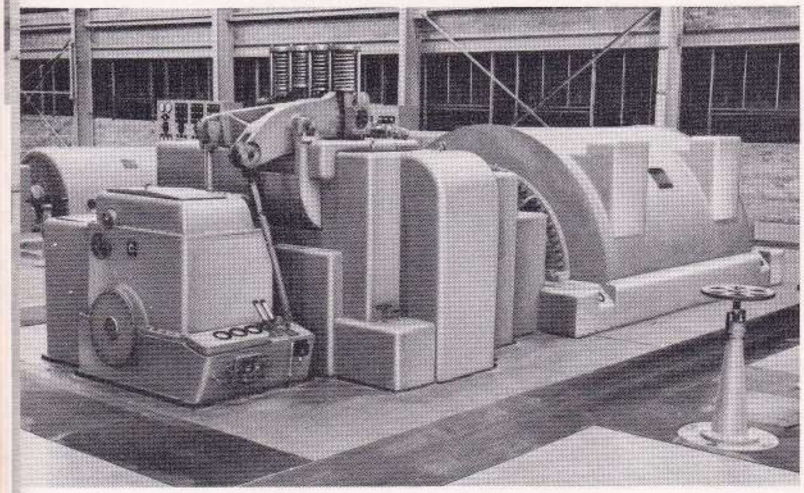
SINGLE AUTOMATIC EXTRACTION NONCONDENSING

Single-automatic-extraction, noncondensing steam turbines are often applied where:

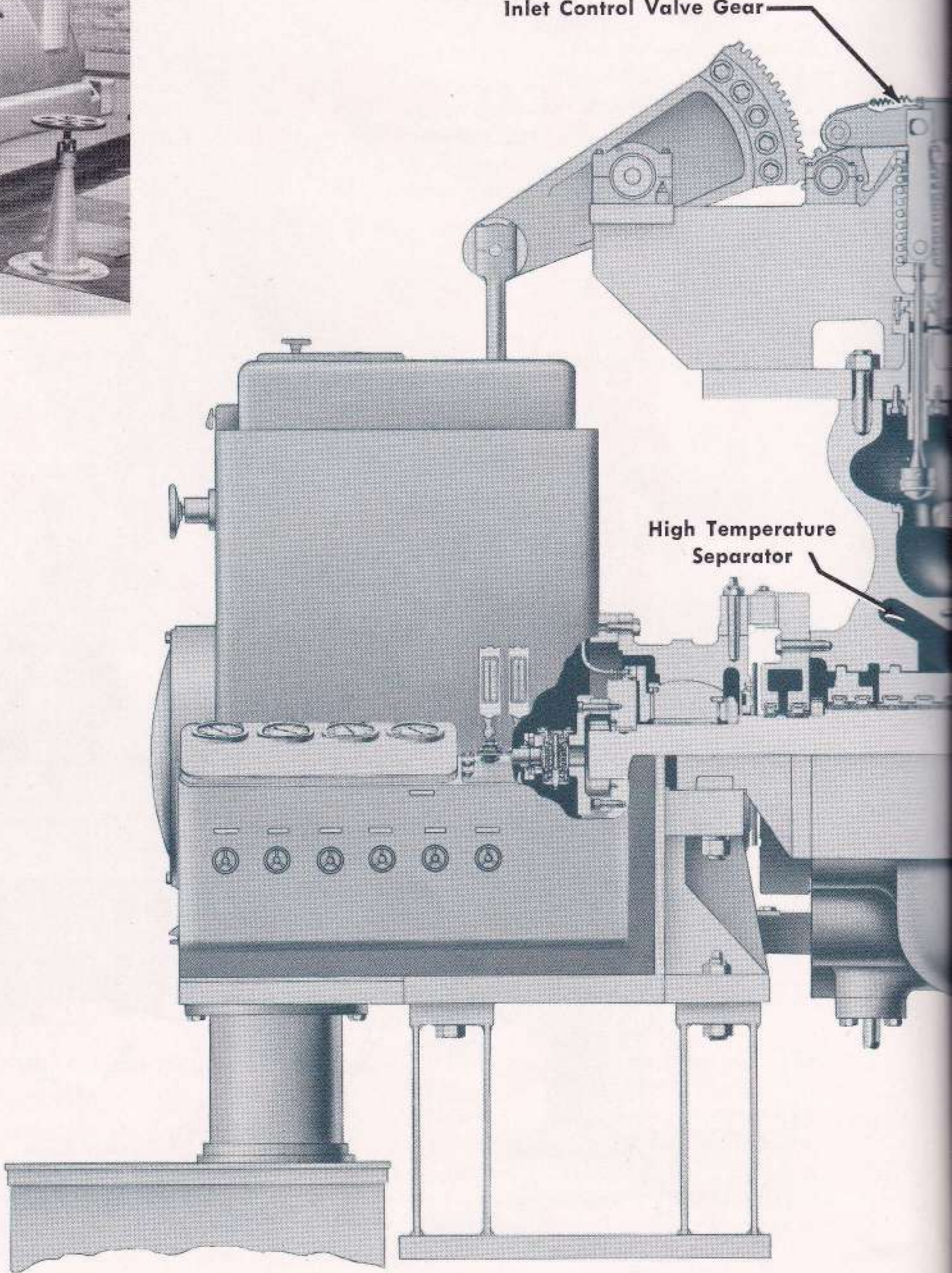
1. There is continuous demand for process steam at two pressures.

2. Higher pressure steam can be supplied by extraction, and lower pressures furnished by exhaust steam.

The exhaust and extraction pressures are regulated by pressure governors and generally the turbine is operated in parallel with another source of power which is capable of taking care of fluctuations in the load.



General Electric single-automatic-extraction, noncondensing steam turbine in a paper plant.



DOUBLE AUTOMATIC EXTRACTION NONCONDENSING

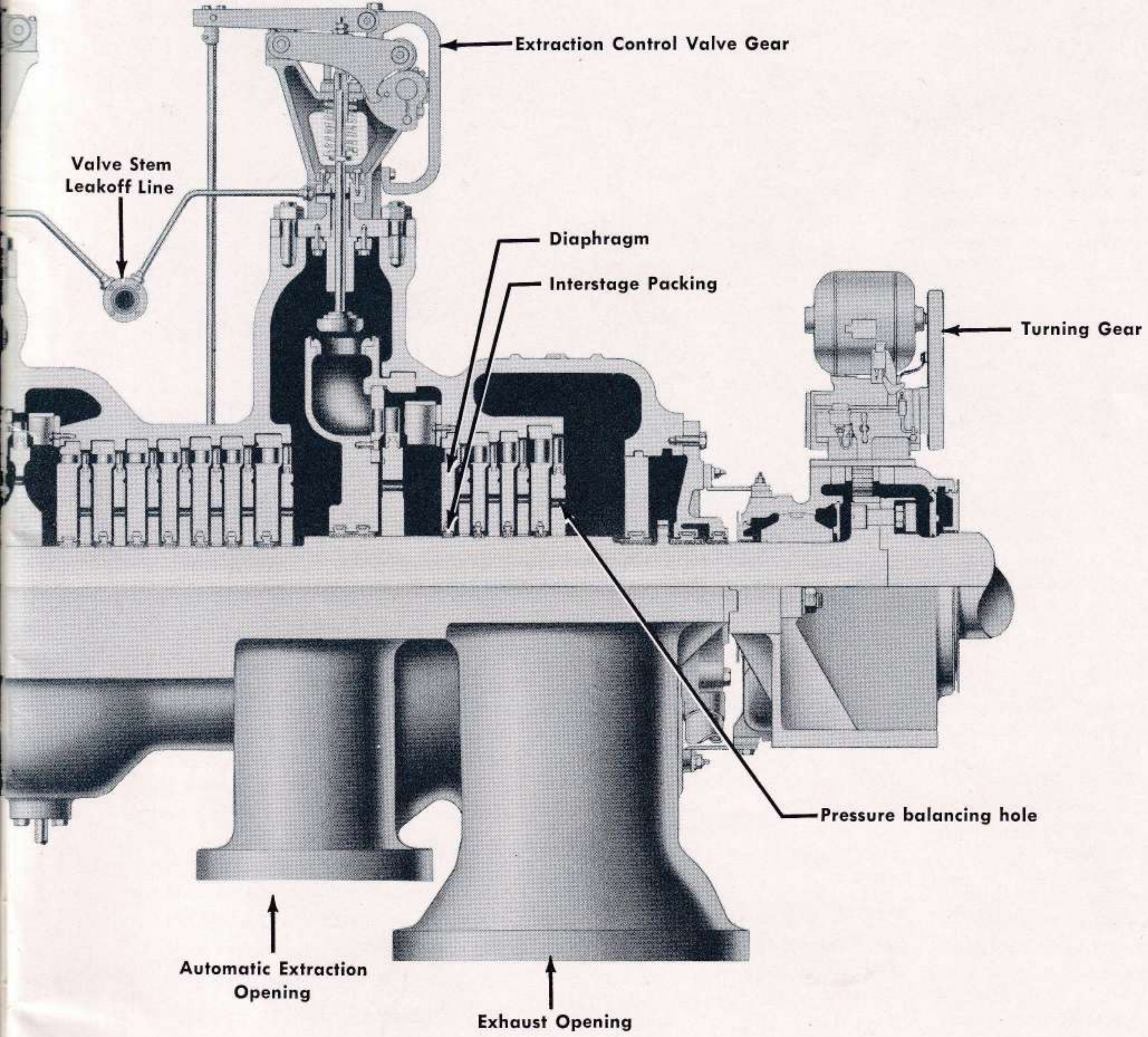
Double-automatic-extraction, noncondensing steam turbines can be applied where:

1. There is continuous demand for low-pressure exhaust steam and

2. there is a requirement for process steam at two higher pressures.

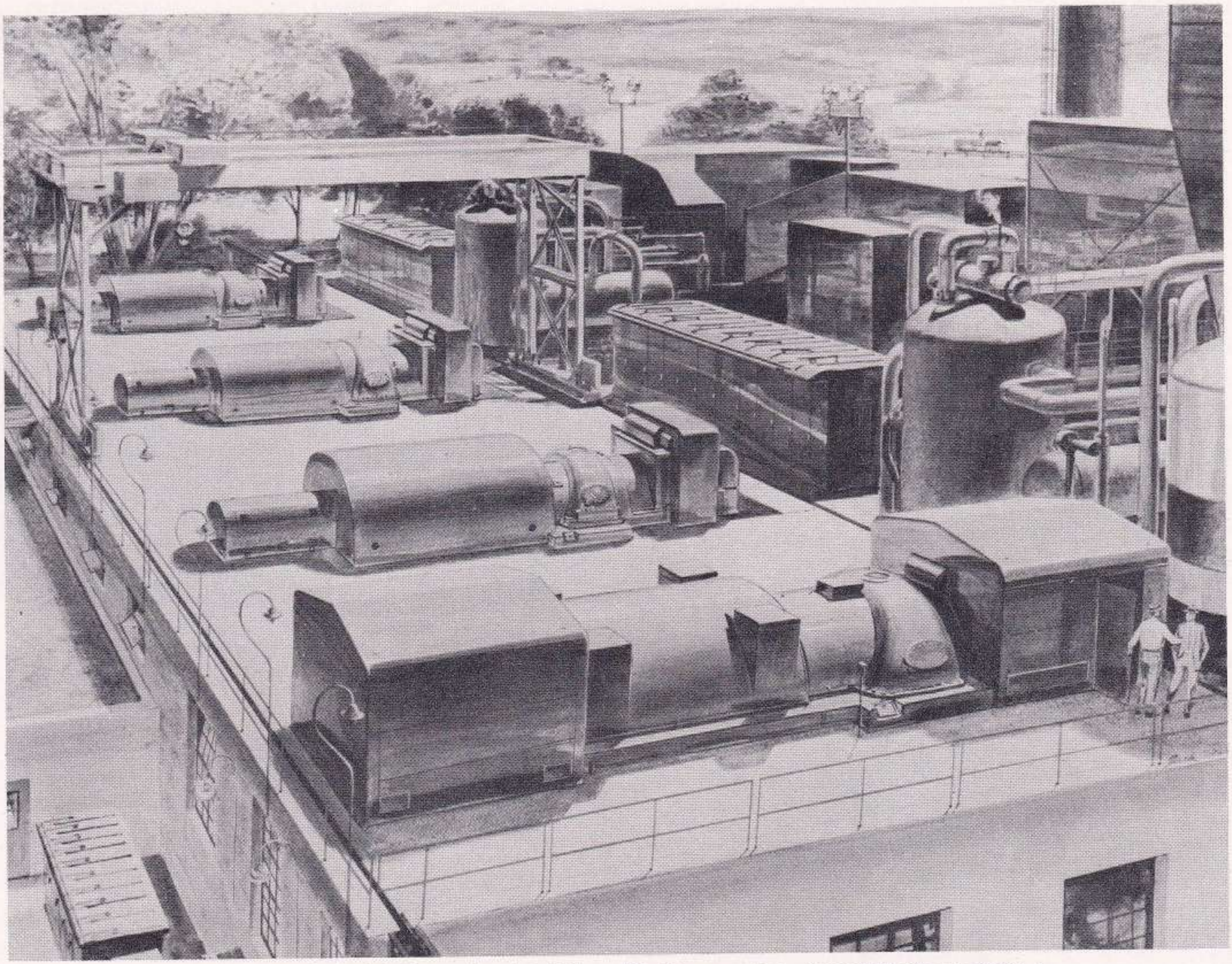
The turbine control system is designed to maintain all of these pressures as desired regardless of fluctuations in the various process requirements. The unit is usually operated in parallel with other sources of power to supply the demands for electricity in case of reduced process steam requirements.

The extreme flexibility and accuracy of General Electric's extraction turbines is especially evident in this sort of application where demands for steam may fluctuate over wide ranges. Yet extraction pressures will be held constant at the desired settings. The turbine control system can be designed to maintain constant speed or load, or extraction pressures, or exhaust pressures, or a combination of these over a wide range of process steam requirements or electrical load.



Sectional view of General Electric single-automatic-extraction, noncondensing steam turbine.

Special Turbine Applications



One of General Electric's first outdoor installations of turbine-generators. General Electric can design a turbine-generator to operate outdoors in climates ranging from heavy sand-storm areas to areas with temperatures as low as —40 F.

Occasionally, certain modifications must be made to a turbine-generator unit to adapt it to the special requirements of a customer. Because of extreme flexibility in the design and manufacture of General Electric turbines, almost any special needs can be met. Here are a few.

MIXED PRESSURE

A turbine designed for mixed pressure makes good use of a supply of low-pressure steam which might otherwise be wasted. The turbine is equipped with two steam inlets. One admits steam at station pressure; the other inlet admits low-pressure steam. The turbine governor is arranged so that any supply of low-pressure steam is fully used before high-pressure steam is admitted to the turbine. The turbine will run at full load on either low-pressure, high-pressure or a combination of steam pressures, to give you maximum station efficiency.

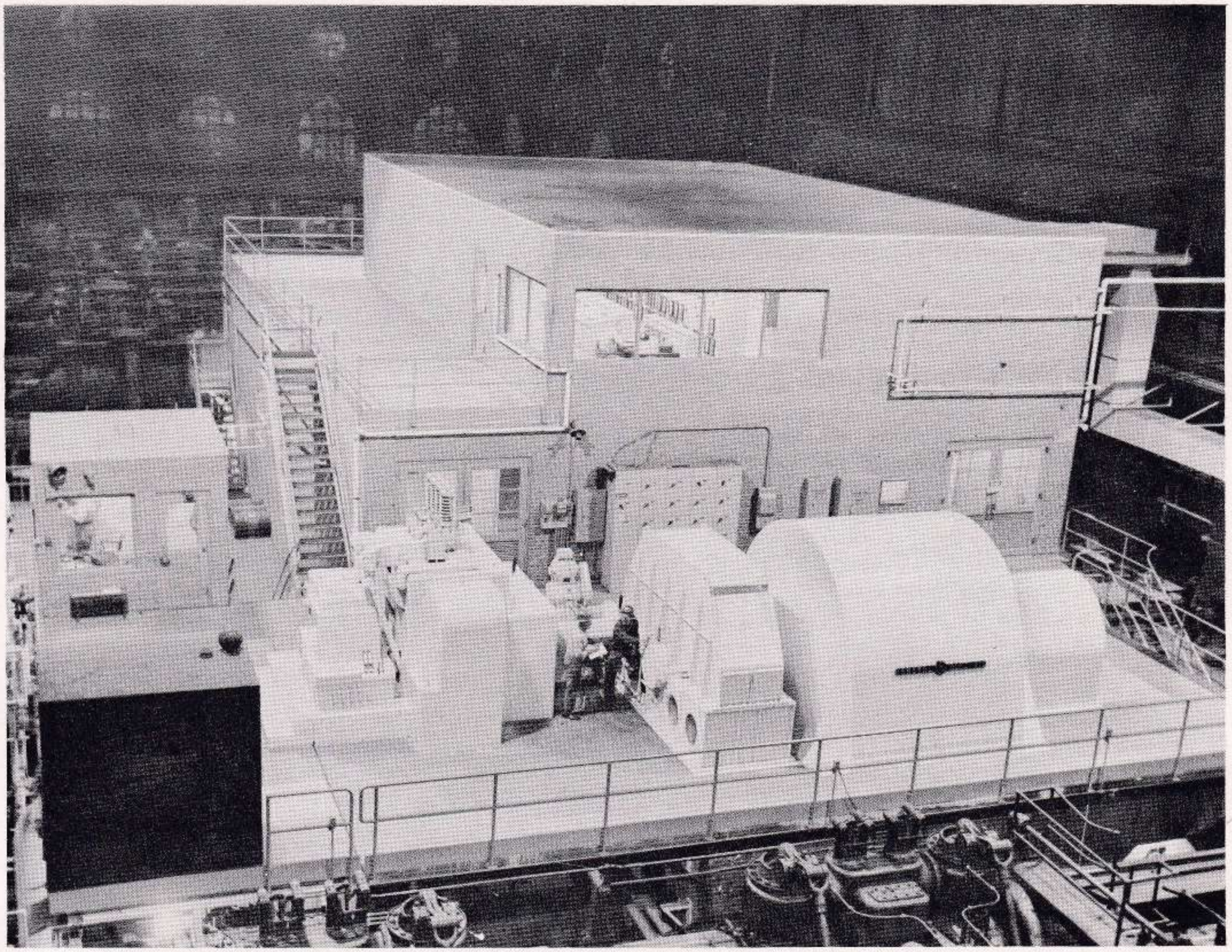
MIXED PRESSURE EXTRACTION

A mixed-pressure extraction turbine is generally applied when low-pressure steam is required for process use, and where the supply is variable. If the available supply of low-pressure steam exceeds the process requirements, the surplus is fed to the turbine, reducing the flow of high-pressure steam to the turbine. However, if the quantity of low-pressure steam is insufficient for process requirements, the difference is extracted from the turbine. Improved plant efficiency results from the production of power from surplus low-pressure steam, or the use of extracted steam for plant processes.

OUTDOOR INSTALLATIONS

G.E. has installed over 40 outdoor turbine-generators which are operating successfully under a variety of conditions. One unit operates in an area subject

To Fill A Variety of Needs



A recent General Electric geared turbine-generator installation producing 25-cycle power in a steel plant.

to heavy sand storms; another is on the seacoast, where salt water corrosion is the major problem; and a third unit is designed for operation at temperatures as low as —40 F.

Weatherproofed housings on G-E outdoor units are designed to help protect turbine-generators from the elements, and at the same time provide easy access for routine servicing of valve gear, control mechanism, and the exciter.

Whether turbine-generators are required for indoor or outdoor service, General Electric is ready with the most advanced turbine-generators available.

25-CYCLE OR DC GEARED TURBINE-GENERATORS

The 25-cycle or DC geared turbine-generators are driven at speeds lower than normal turbine speeds through General Electric single-reduction helical gears. High-speed helical gears are a G-E specialty. Built to rigid standards of tooth spacing, high-quality surface finish, and precision, these gears bring you reliability, efficiency, quiet operation, long life and low maintenance.

LOW PRESSURE

Where there is a steady supply of low-pressure steam from the exhaust of reciprocating engines or other sources, which would be wasted to atmosphere, the plant efficiency can be improved and the capacity increased by the installation of a low-pressure turbine. While such an installation would not affect the boiler plant, a condenser for the turbine would be required. Since the low-pressure turbine will produce power without increasing the steam demands on the boilers, this is a source of economical by-product power.

DUAL PRESSURE

A dual pressure turbine is arranged to operate at either or both of two steam pressures, with or without minor changes in the turbine.

What Accurate Turbine Governing Means to You

WHY IT IS IMPORTANT

Completely successful turbine performance and maximum operating economy depend on a highly accurate and stable governing system. The governing system should perform three functions which all add up to operating economy.

1. Constant frequency is essential for the successful operation of any electrical system. The parallel operation of turbine-generators, the holding constant of the output of driven equipment such as paper machines and pumps, and the operation of such special machines as synthetic fiber spinning equipment, require the most accurate governing. The General Electric mechanical-hydraulic governing system, shown on these pages, holds electrical frequencies constant within any plant requirement.

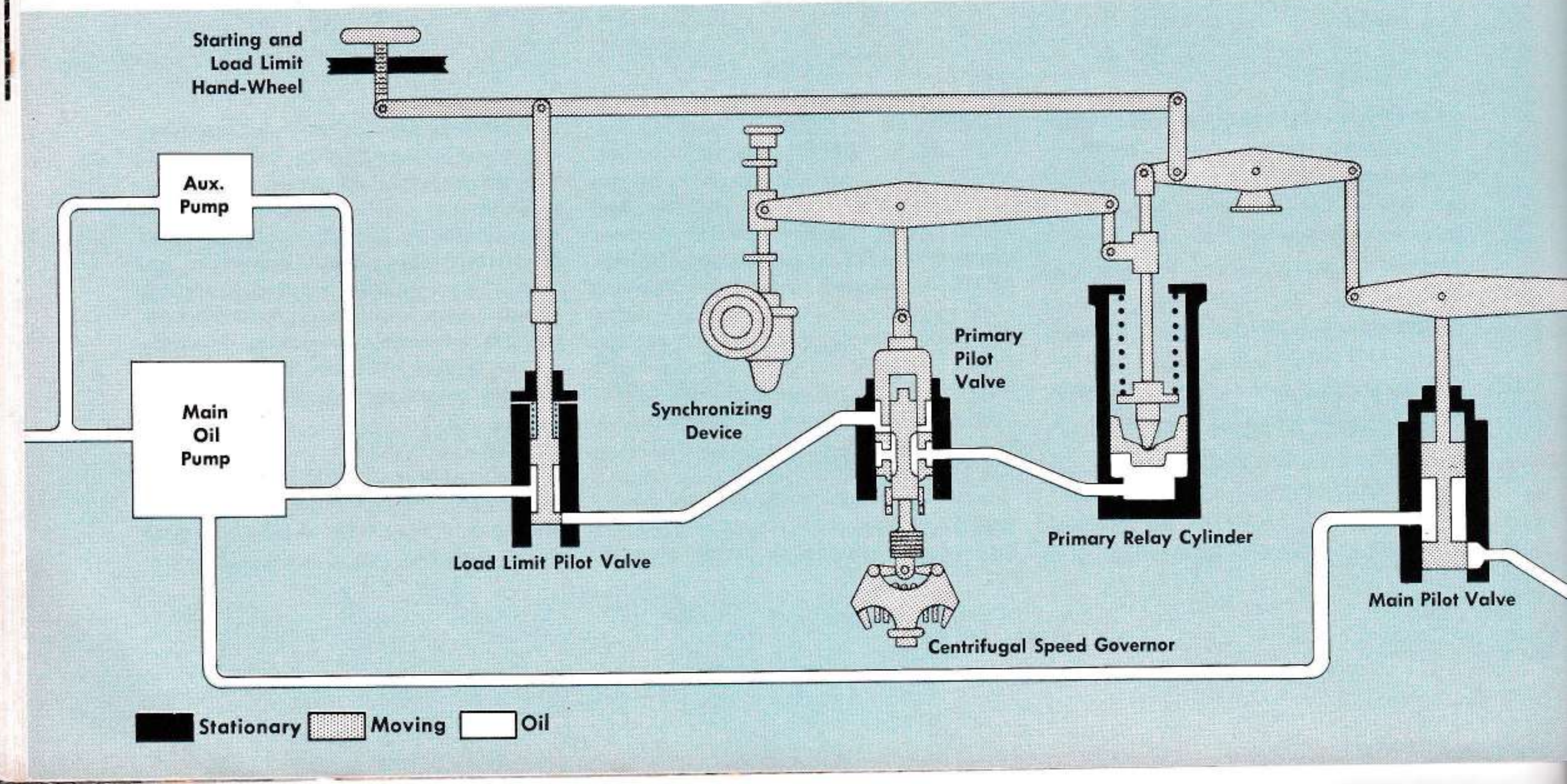
2. Accurate governing is needed to hold inlet, extraction or exhaust pressures constant on automatic extraction units.

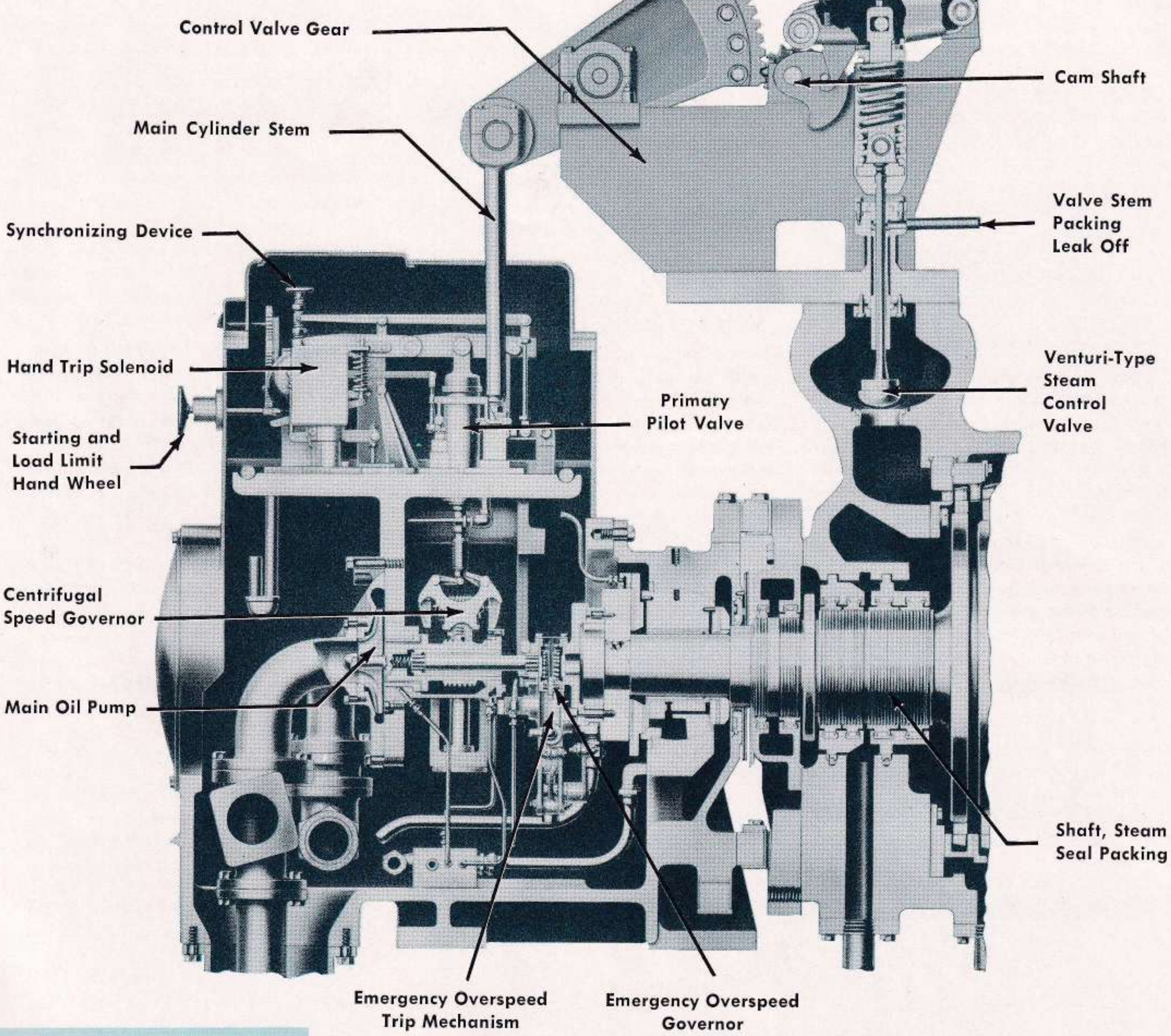
3. The governing system must react quickly after a change in system conditions. The sensitive mechanical-hydraulic system has a high speed of response so that it can handle changes in turbine operating conditions faster than any other system.

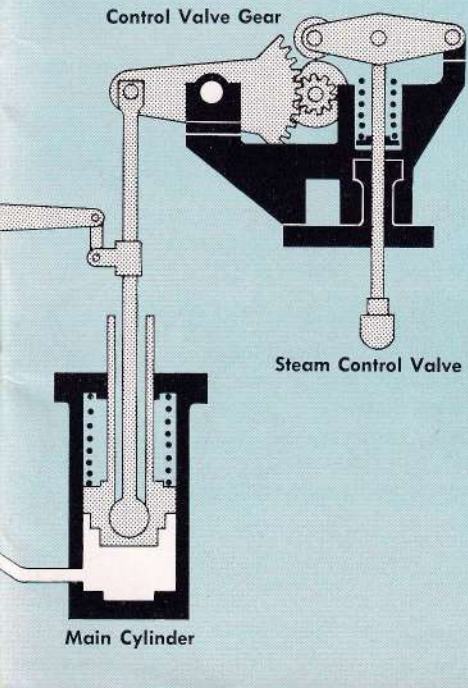
These are just three of the reasons why accurate governing is so important. The speed of response, accuracy and flexibility of this system are so great that G.E. builds this same basic governing system into all of its turbine-generators regardless of size.

The following pages show some of the features which make General Electric turbines more accurate and stable.

Cross section of front standard of General Electric steam turbine, showing mechanical-hydraulic governing system.




Control Valve Gear
Cam Shaft
Main Cylinder Stem
Valve Stem Packing Leak Off
Synchronizing Device
Hand Trip Solenoid
Venturi-Type Steam Control Valve
Primary Pilot Valve
Starting and Load Limit Hand Wheel
Centrifugal Speed Governor
Main Oil Pump
Shaft, Steam Seal Packing
Emergency Overspeed Trip Mechanism
Emergency Overspeed Governor

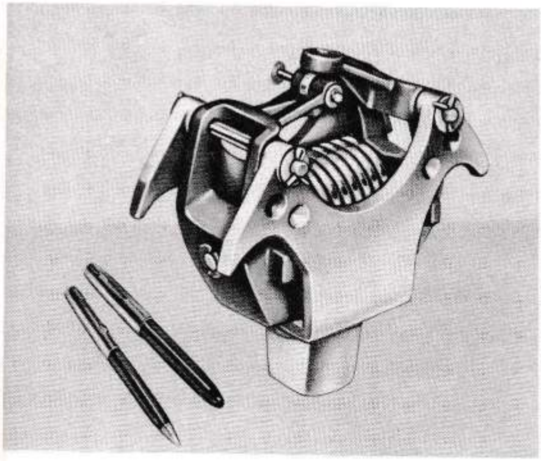


TURBINE SPEED GOVERNING

HOW THE TURBINE GOVERNOR OPERATES. During starting, the operator brings the turbine up to rated speed by turning the starting *handwheel*. The *main pump* supplies oil to the system through the *load limit pilot valve*. If the turbine tends to slow down with increased load, the *centrifugal speed governor*, gear driven from the turbine shaft, opens the *primary pilot valve* wider. This valve admits oil to the *primary relay cylinder* which simultaneously opens the *main pilot valve* wider through a mechanical linkage and restores the primary pilot valve bushing to a new position. Pressure is increased in the *main cylinder* which lifts the *steam control valves* and allows more steam to enter. When the main cylinder is lifted, it restores the main pilot valve to its controlling position and the system is in equilibrium at the new load. If the turbine tends to speed up on decreased load, the system operates in reverse.

SPEED GOVERNOR — HEART OF THE REGULATING SYSTEM

The mechanical speed governor, which is the heart of the regulating system on General Electric turbines, is gear-driven from the turbine shaft. It is, therefore, instantly responsive to any changes in turbine speed — relaying this information with accuracy and speed.



Centrifugal fly ball governor — heart of the speed regulating system.

The speed governor does no actual work, but merely signals changes to the primary rotating pilot valve. This is important, since the accuracy and reliability of any governor varies inversely with the amount of work required of it.

On General Electric turbines, the speed governor is of the centrifugal fly-ball type, and the centrifugal force is balanced by a spring between the weights. When a turbine is operating alone, the governor holds the speed essentially constant even when load on the turbine varies. In fact, response to load changes is so fast that the turbine speed will be held below trip speed even though full load is dropped from the generator instantaneously.

The primary rotating pilot valve moves against fluid friction only, since it is floating on a film of oil, instead of having to move against the higher forces involved in rubbing friction. In addition, the rotation of the pilot valve scrubs away any sludge or varnish which would form if it were stationary. These deposits would increase the friction of a stationary valve and make it bind.

In addition to high accuracy and quick relaying, safety and dependability are increased by the governing system's insensitivity to dirt or changes in oil viscosity. This assures you of reliability over the life of the unit.

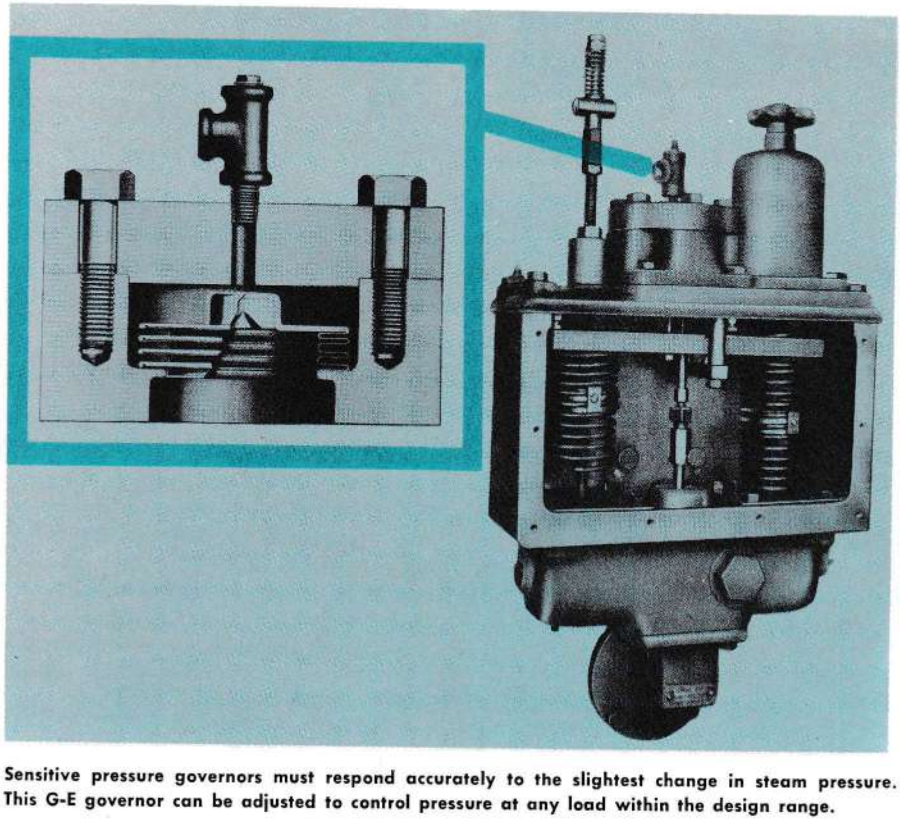
When operating in parallel with other units, turbine speed is determined by the frequency of the system, the governor controlling the load on the generator. A motor-operated synchronizing device, controlled from the switchboard, is used to vary the speed when synchronizing, and to vary the load after synchronizing.

Governing refinements are but one of G.E.'s major contributions to turbine-generator efficiency and accuracy.

SENSITIVE, MORE ACCURATE PRESSURE GOVERNING

A pressure governor may be provided to control admission, extraction, inlet and exhaust pressures or a combination of these. It provides broad instantaneous regulation. Also, settled regulation is held within narrow limits, in terms of steam pressure change versus governor signals.

Any change in steam pressure will cause a movement of the bellows in the pressure governor. The maximum bellows travel required is only sixteen thousandths of an inch. This contributes to the governor's durability and reliability because it imposes only negligible stress on the bellows. This minute travel is amplified and relayed to the interconnecting mechanism of the governing system to obtain rapid return to the desired constant pressure.



Sensitive pressure governors must respond accurately to the slightest change in steam pressure. This G-E governor can be adjusted to control pressure at any load within the design range.

The pressure governor may be set to control pressure at any level within the design pressure range by adjustment of the loading spring. The range of adjustment of both instantaneous and settled regulation is very broad and the springs can be adjusted to provide: (1) increase of pressure with increased flow, (2) no change of pressure through the flow range, or (3) decreasing pressure with increased flow. In addition, the time rate of correction is adjustable so that the pressure governor and its control mechanism may be operated at the optimum rate of correction permitted by the piping system to which it is connected.

The pressure governor can be adjusted to parallel other equipment including turbine-generator sets or pressure reducing stations.

The pressure governor provides a flexible, rapid, more accurate and more reliable means of holding constant steam pressure.

OVERSPEED GOVERNOR AND STOP VALVE

BETTER PROTECTION AGAINST OVERSPEED

Adequate protection of turbine-generators against overspeed requires two independent governors. Double protection against overspeed is provided by G.E.'s extremely reliable governing system and control valves, and by an overspeed governor and quick-closing throttle or stop valve. The latter operates entirely separately from the main governing system.

The overspeed governor is adjusted to completely shut off steam if the turbine should exceed normal speed. It is usually set up to trip at 10 percent overspeed. Better overspeed protection is provided by a bolt-type governor, consisting of a spring-opposed unbalanced weight, assembled in a cartridge and mounted in the turbine shaft. If the turbine speed increases beyond normal for any reason, centrifugal force causes the bolt to move outward and strike an emergency tripping device, which closes the throttle or stop valve, instantly shutting off all steam to the turbine.

Since the overspeed governor operates in an oil atmosphere, the possibility of rusting or sticking is minimized, and more reliable operation is assured.

OIL-OPERATED STOP VALVES

The stop valve has just two important functions: to admit steam to the turbine during operation, and to shut off steam quickly and completely when necessary. General Electric oil-operated, quick-closing, stem-sealed stop valves are designed and manufactured to perform these functions in the safest and most efficient manner.

The stop valve has two positions — either completely open or fully closed; it is not used as a throttle valve. The stop valve is spring-loaded to assure better high speed closing when tripped by the emergency overspeed governor. The stop valve may also be tripped closed by hand at any time.

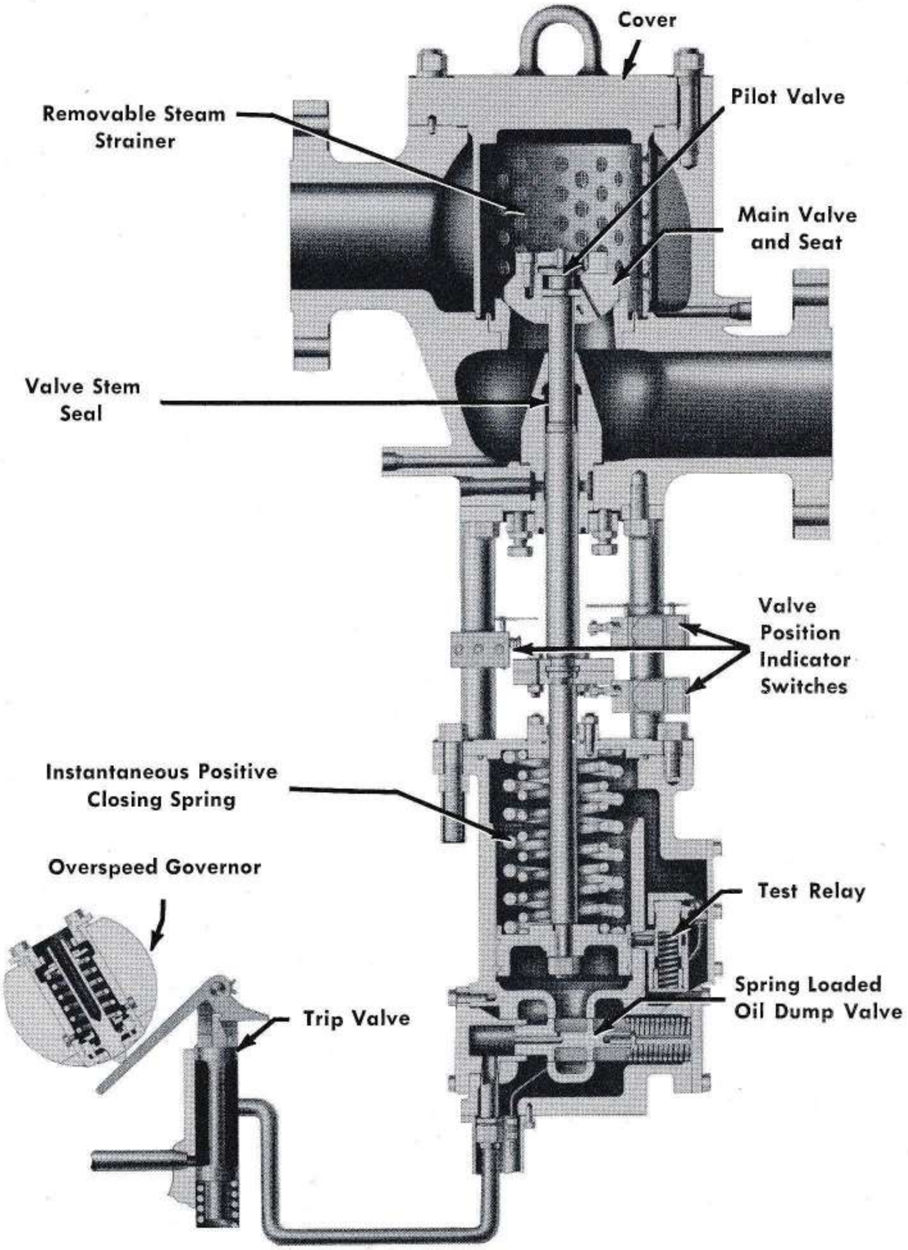
The valve stem is made in two diameters to provide the stem-sealing feature. The transition in diameter forms a seating surface, so that at full opening there is no steam leakage along the stem. The stem-sealed feature provides better protection against sticking of the stop valve. Large clearances on the upper part of the valve stem assures freedom of operation. As a further safety feature the stop valve is so designed that it cannot open unless the turbine control valves are closed.

The stop valve is designed so that it can be tested periodically for freedom of action, while the turbine is carrying full load. This additional safety feature gives further assurance that the valve stem is free and ready to operate if tripped by any of the safety devices in the control system.

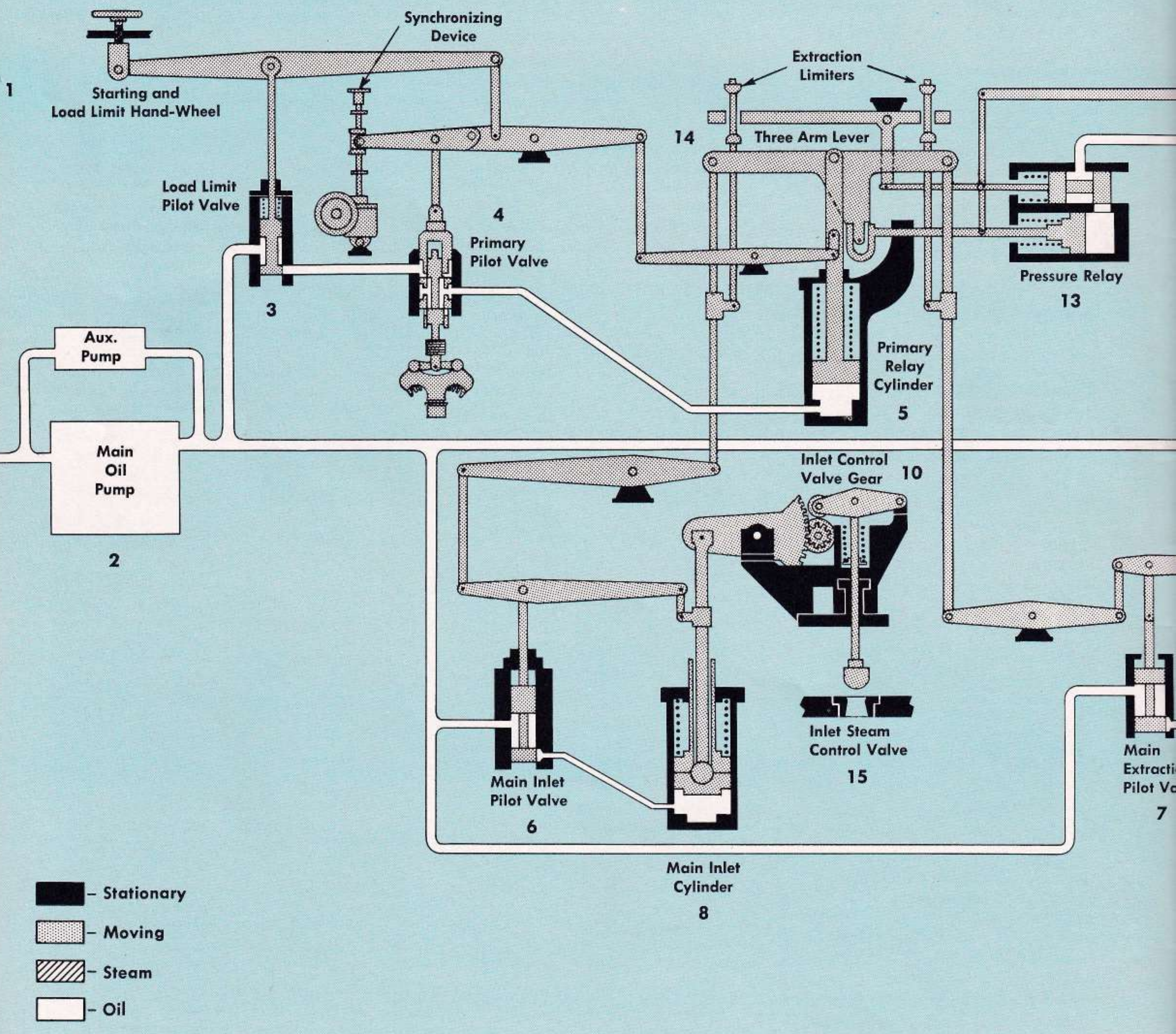
The stop valve, which is usually located beneath the floor, is equipped with an internal steam strainer. A removable basket makes cleaning easy.

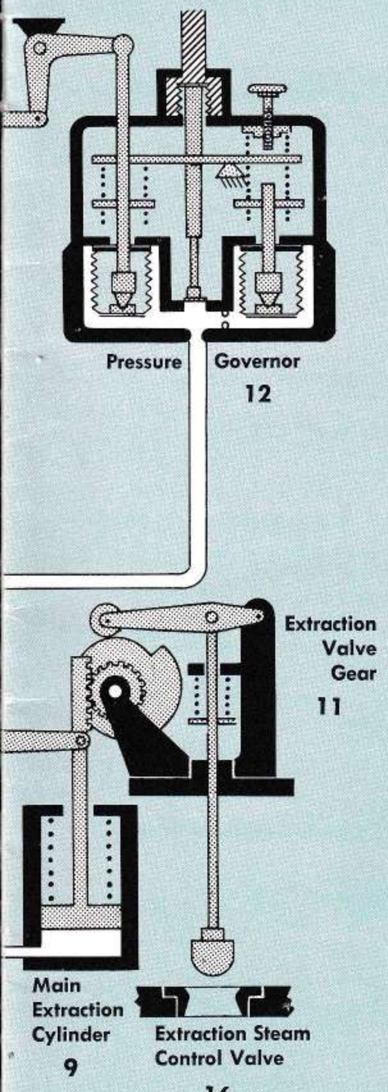
Combined trip-throttle valves are used on smaller units.

Castings for stop and trip throttle valves are subjected to critical tests, before they are even accepted for machining. X-ray and magnetic particle tests are given to all valve castings to assure that the castings are free of any flaws which would permit steam leakage. Careful manufacturing plus quality control produce a more completely reliable trip valve. The seating surface of the stop valve, plus its built-in pilot valve and the stem seal have contact areas, of hard faced material which resist erosion, corrosion, and mechanical damage. This assures a tight-valve seal, even after years of use.



This composite drawing shows how the emergency governor gives better protection against overspeed. If the turbine starts to overspeed, the bolt in the emergency governor moves out and trips a latch which cuts off the oil pressure supply and dumps the oil from the valve.


Synchronizing Device
1
Starting and Load Limit Hand-Wheel
Extraction Limiters
14
Three Arm Lever
Load Limit Pilot Valve
4
Primary Pilot Valve
3
Pressure Relay
13
Aux. Pump
Primary Relay Cylinder
5
Main Oil Pump
2
Inlet Control Valve Gear
10
Main Inlet Pilot Valve
6
Inlet Steam Control Valve
15
Main Extracti
Pilot Va
7
Main Inlet Cylinder
8
▇ – Stationary
▒ – Moving
▨ – Steam
☐ – Oil



TURBINE EXTRACTION GOVERNING

You can be assured of accurate control of steam flow demands with this sensitive G-E governing system.

The sensitive General Electric governing system will act to satisfy the conditions for any combination of load and extraction steam flow demands within the limits of the turbine's capability.

During starting the operator brings the turbine up to rated speed by turning the hand wheel (1). The main pump (2) supplies oil to the system through the load limit pilot valve (3).

If the turbine tends to slow down with increased load, the centrifugal speed governor, gear driven from the turbine shaft, opens the primary pilot valve wider (4). This valve meters oil to the primary relay cylinder (5) which simultaneously opens both the main inlet pilot valve (6) and the main extraction pilot valve (7) wider through a mechanical linkage and restores the primary pilot valve bushing to a new position.

Pressure is increased in the main inlet cylinder (8) and the main extraction cylinder (9). This lifts the inlet (10) and extraction valve gears (11) and allows more steam to pass straight through the turbine.

The areas under the valves and the mechanical linkages are so selected that this increased amount of steam flow will not cause the extraction pressure to be changed.

When the main inlet cylinder and the main extraction cylinder are lifted, they restore the main extraction and main inlet pilot valves to their controlling positions. The system is then in equilibrium with the new load. If the turbine tends to speed up on a decreased load, the system operates in reverse.

The pressure governor (12) acts to maintain constant extraction pressure when the demand for steam flow from the extraction opening is changed.

The valve located in the center of the pressure governor constantly meters a flow of oil. This oil flow maintains a certain pressure against the controlling bellows on either side of the governor. When the small bellows at the top of the governor detects a decrease in steam pressure, the plunger is allowed to move upward. This increases the flow of oil past the plunger and decreases the oil pressure on the two bottom bellows.

The decrease in oil pressure expands the bellows, which, by mechanical linkage, moves the pressure relay pilot valve. Pressure is then increased in the pressure relay (13). This increased oil pressure causes the three arm lever (14) to rotate counterclockwise and at the same time restore the pilot valve to its controlling position. This motion of the three arm lever will cause the inlet steam control valve (15) to open and the extraction steam control valve (16) to close. The extraction pressure is thereby increased to the desired level.

Since all of the pilot valves are restored to their controlling positions, the system is in equilibrium, the desired speed is maintained and the extraction pressure held constant despite these changes in load and extraction demand.

If the extraction pressure tends to increase because of a decrease in extraction flow demand, the system operates in reverse.

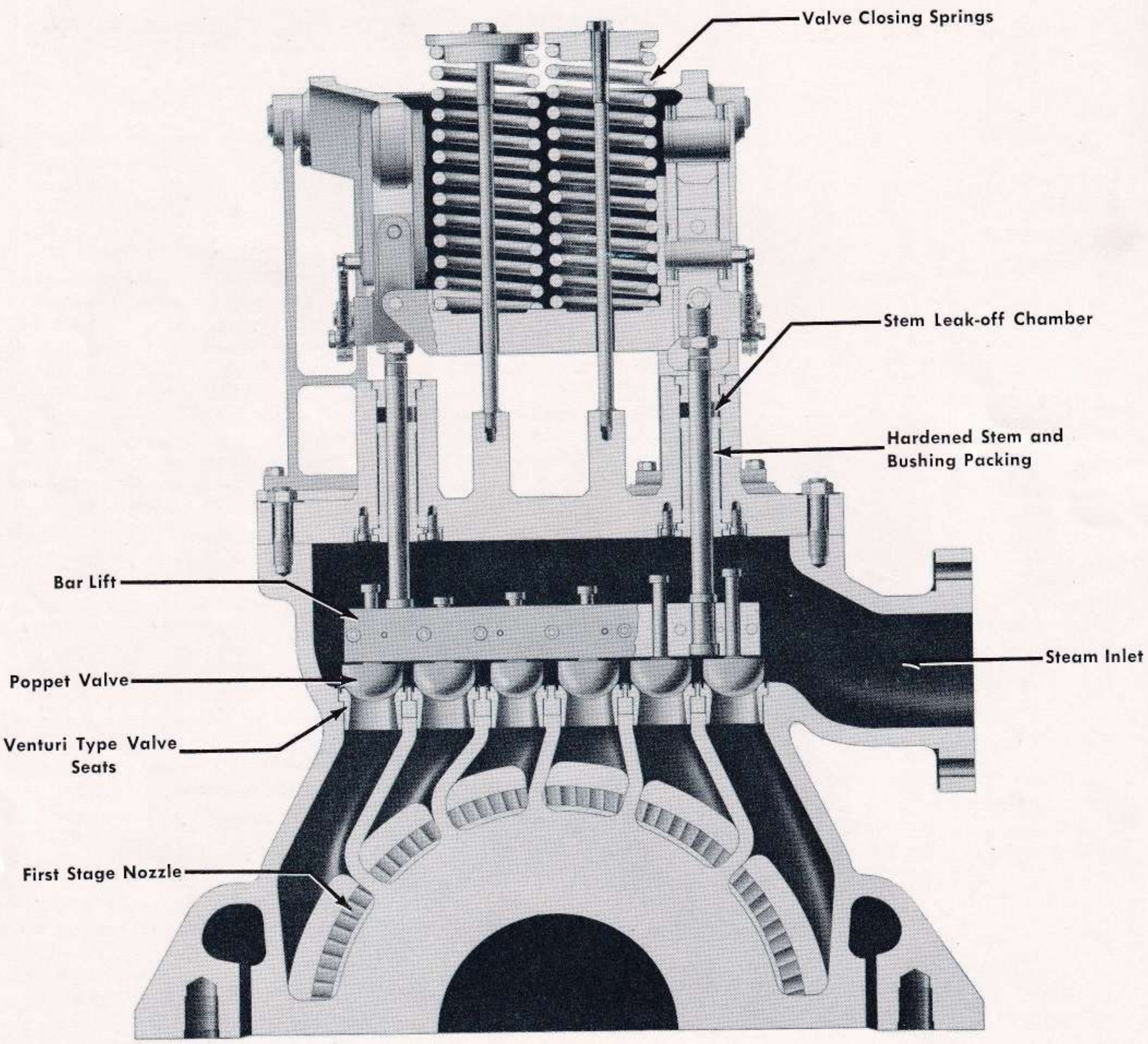
Design and Application Flexibility Made

For flexibility and high efficiency, General Electric uses five types of valve gear.

Each type of valve gear gives sectional nozzle control to assure top efficiency when the turbine or any of its stage groupings is operating with partial steam flow. Valves or ports are opened in sequence with controlled overlap so that smooth governing is obtained.

Flexibility in the design of the casings and governing systems permits selection of the proper type of valve gear for each application. Varying steam conditions also influence the selection of either bar-lift, cam-lift, spool or grid valve gear. For straight condensing and non-condensing turbines, one set of valves controls the steam flow. On automatic extraction units, additional sets of valves control pressures at extraction and admission points by regulating the flow of steam to the stages that follow.

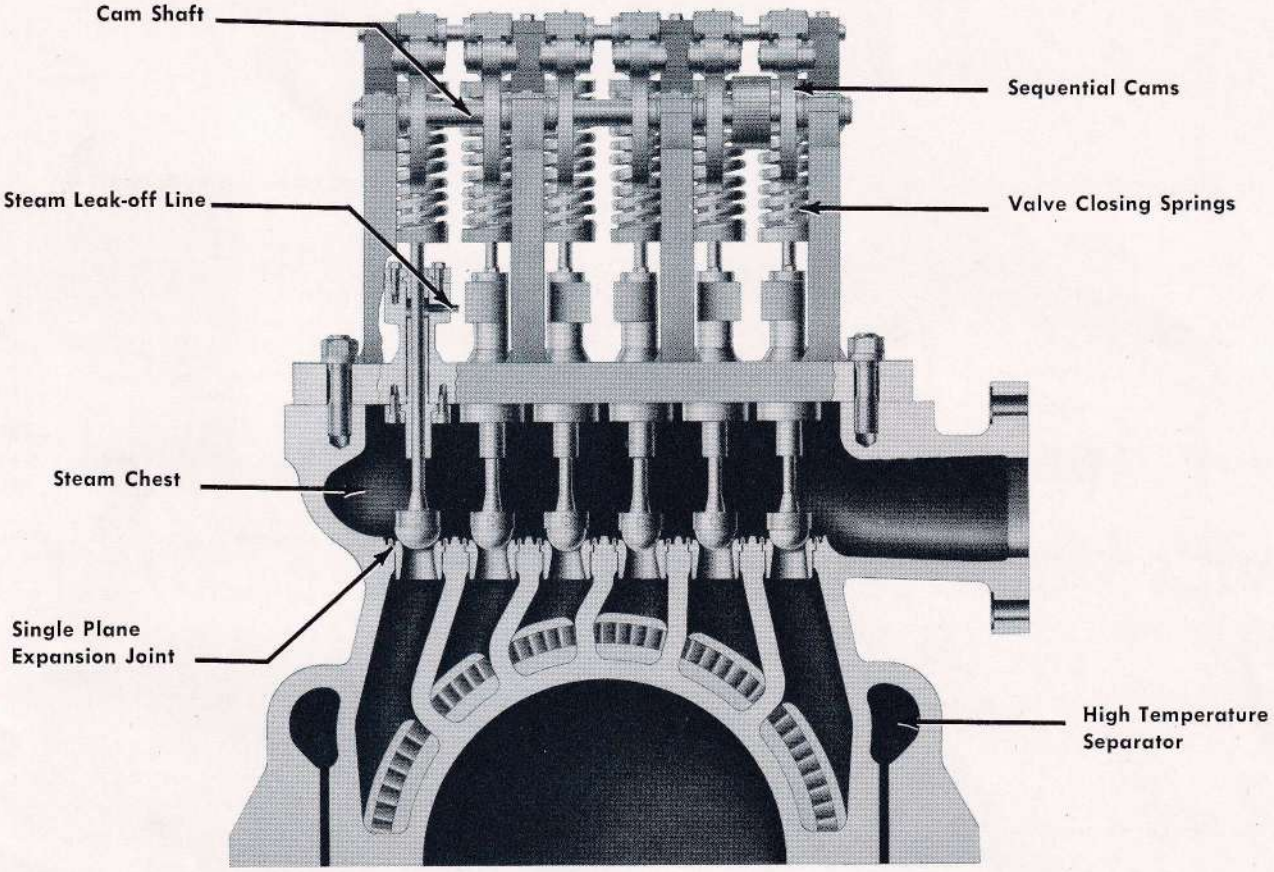
LEVER-OPERATED BAR-LIFT VALVE GEAR



Valves of lever-operated-bar-lift valve gear are lifted in sequence by the bar. A lever extends to the steam chest and is positioned by the hydraulic cylinder under control of the governor. This permits the hydraulic cylinder to be safely away from the high temperatures and pressures of the steam parts.

Possible by Five Types of Valve Gear

CAM-LIFT VALVE GEAR



The valves in cam-lift valve gear are lifted in sequence by cams on a shaft. The cam shaft is rotated by a rack and gear arrangement which connects it to the operating cylinder. A return spring provides the downward force to close each steam valve. As a further protection, a hook on each cam lever exerts an additional closing force to press any valve back into the return position, if it should fail to return automatically.

DIRECT-OPERATED BAR-LIFT VALVE GEAR

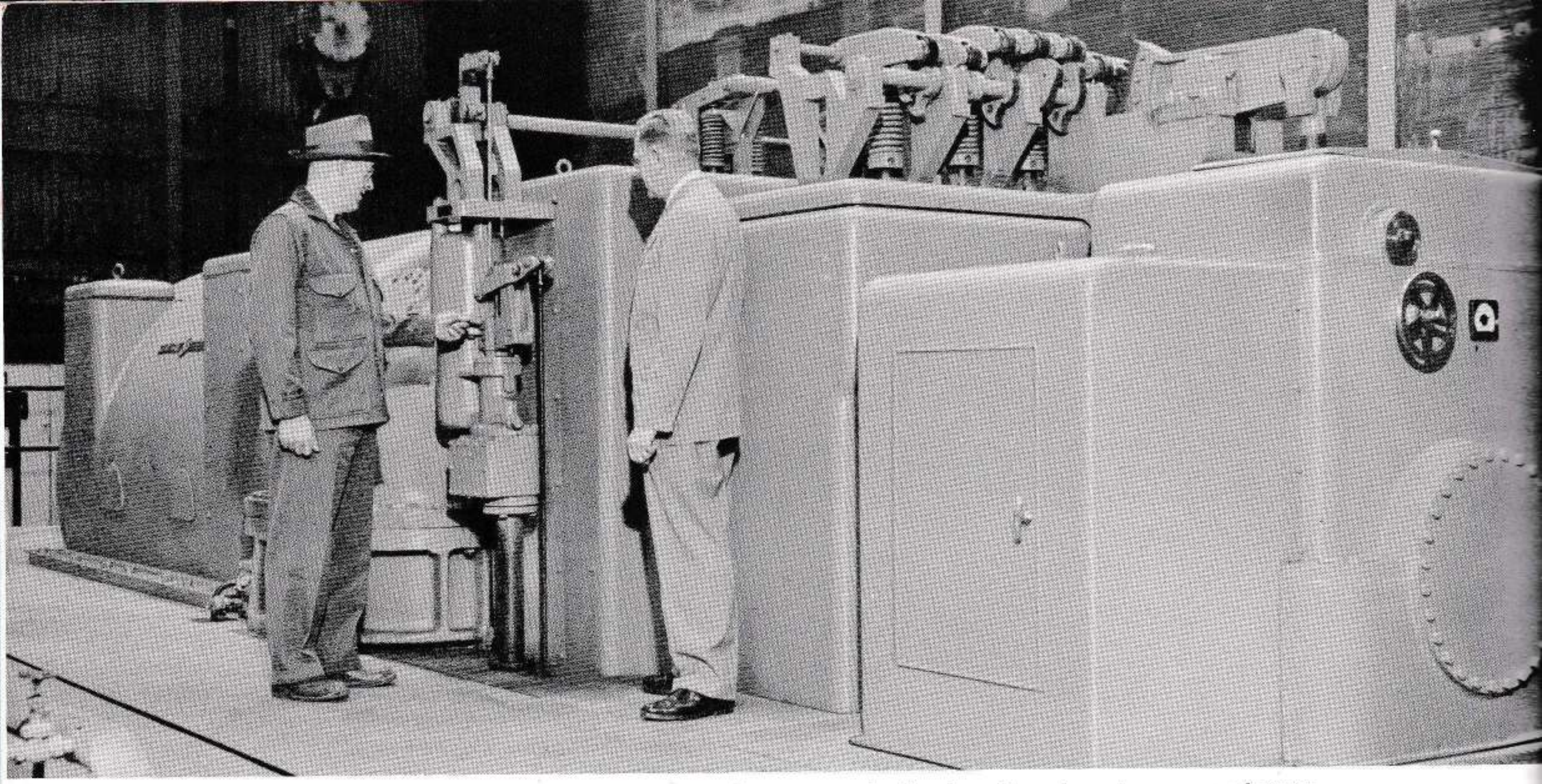
Direct-operated-bar-lift valve gear is usually used with lower steam pressures and temperatures and lower flows. Valves are lifted in sequence by the bar, which is raised or lowered by a hydraulic cylinder, under control of the governor.

SPOOL-VALVE GEAR

Spool valves are used on the extraction turbines to handle large volume flows of intermediate or low pressure steam. The spool valve is double seating which greatly increases the total valve area.

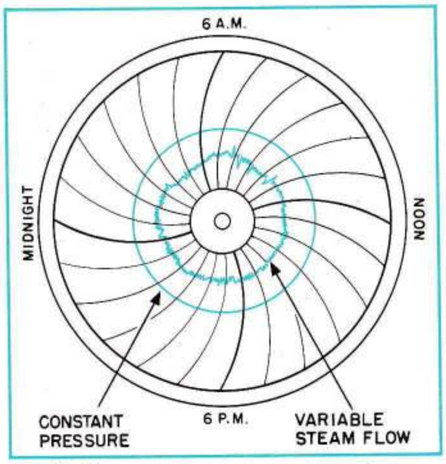
GRID-VALVE GEAR

Grid valves are occasionally used on extraction turbines to handle large volumes of very low-pressure steam. Valve ports are opened and closed in sequence when the grid valve is rotated by the operating mechanism.

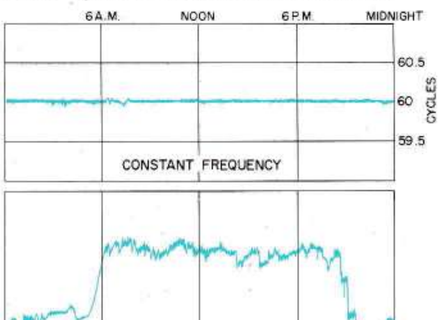


General Electric single-automatic-extraction steam turbine-generator in the plant of a pulp and paper manufacturer.

G-E Turbine Governing Design Pays Off with Stable Frequency, Accurate Extraction



Despite fluctuating steam demand sensitive governing equipment keeps pressure constant.



Frequency stays constant at 60 cycles while the kilowatt load fluctuates.

Stable 60 cycle electric frequency and precisely controlled extraction steam pressure are essential in manufacturing processes in the pulp and paper industry. The General Electric turbine-generator installation at the plant of such a manufacturer in the northwestern part of the United States demonstrates the precise performance made possible by G-E governing equipment. The charts show a typical day in turbine performance at this installation. Mill demands for extracted steam at the General Electric 12,500-kw turbine-generator fluctuated over a wide range. During the entire 24 hour period the sensitive G-E governing equipment held the extracted steam pressure at 44 psig.

The charts show too that the frequency of the generated electricity was held precisely at the desired 60 cycles, despite the widely fluctuating kilowatt load demanded of the turbine.

This is the kind of precise control that pays off where stable frequency and constant extraction pressures are so essential to product quality. This performance is made possible through the simple three arm mechanism on G-E turbines which transmits immediately any signal, no matter how slight it may be, from the pressure governor to the inlet and extraction control valves.

This response is so fast that the turbine speed will be held below trip speed even though full load is dropped instantly from the generator. When emergency conditions occur, this control system helps the turbine "ride through" automatically.

The manufacturer, whose installation is illustrated here, produces kraft paperboard, bleached pulp, plywood and similar forest products at this plant. Two 5,000-kw General Electric turbine-generators were already in operation at this plant when the 12,500-kw unit was put into operation. It was the performance of these two earlier units which influenced this manufacturer to rely again on precisely controlled General Electric automatic extraction turbine-generators for production line product quality control.

Regardless of what your plant manufactures, such results are possible for your processing too. If you have a need for such precise frequency and steam extraction control, contact a G-E application engineer and he will work with your consultants to determine the combination of pressures, temperatures and equipment best for your plant.

G-E Design and Manufacturing Features Which Assure Turbine Reliabilty, Efficiency

1. ADVANTAGES OF THE IMPULSE TURBINE

General Electric, in the early days of the turbine industry, pioneered the impulse design and put its first large unit of this type into service in 1903. This development helped establish the steam turbine as the predominant prime mover in American power stations.

In the G-E impulse turbine, the steam expands in the stationary nozzles, rather than in the buckets. Expanding in the nozzles, the steam attains a relatively high jet velocity, and is directed into the rotating buckets.

This gives the G-E impulse turbine many important advantages. Because the steam expands through the nozzles, pressure unbalances are across the stationary part of the turbine. This means that the axial thrust of the rotor is held to a minimum, eliminating wear on the thrust bearing and increasing its life. Maintenance and the need for adjusting thrust bearings is practically eliminated.

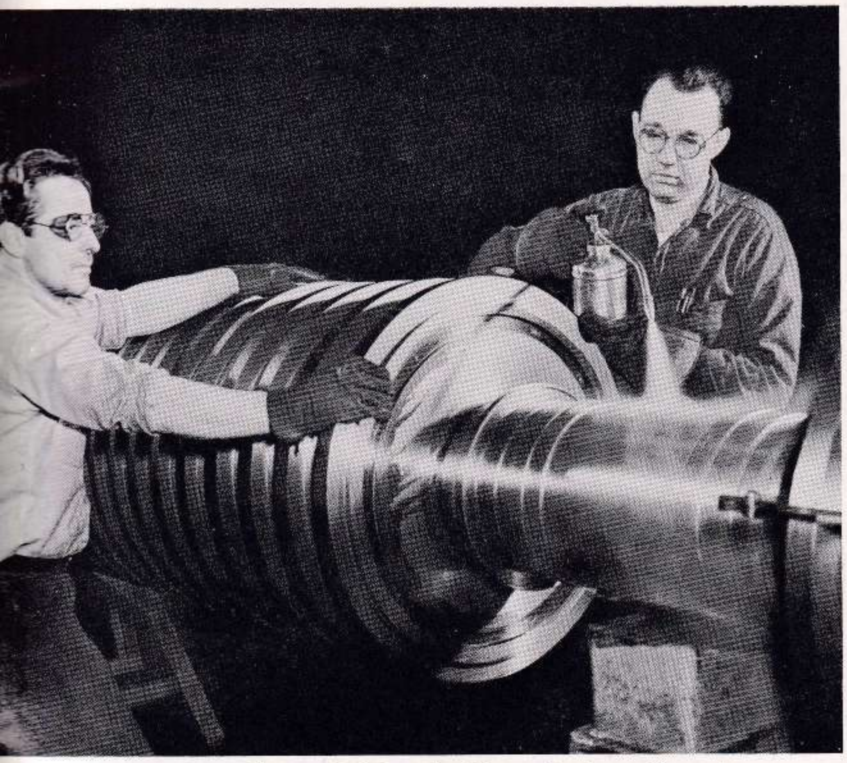
Here is another advantage of G-E impulse turbines — because steam expansion is in the diaphragm, the internal steam seal is around the small diameter of the shaft, rather than around the larger diameter of the rotor. This results in an inherently high-efficiency turbine, because any steam leakage which might occur is restricted to small areas. Since tight sealing is not essential around the buckets — where years of operation could easily reduce sealing effectiveness — turbine efficiency remains high.

Because the thrust bearing has long life, it maintains the correct axial clearance between rotating wheels and stationary nozzle diaphragms—giving high efficiency at all operating conditions, and through total turbine life.

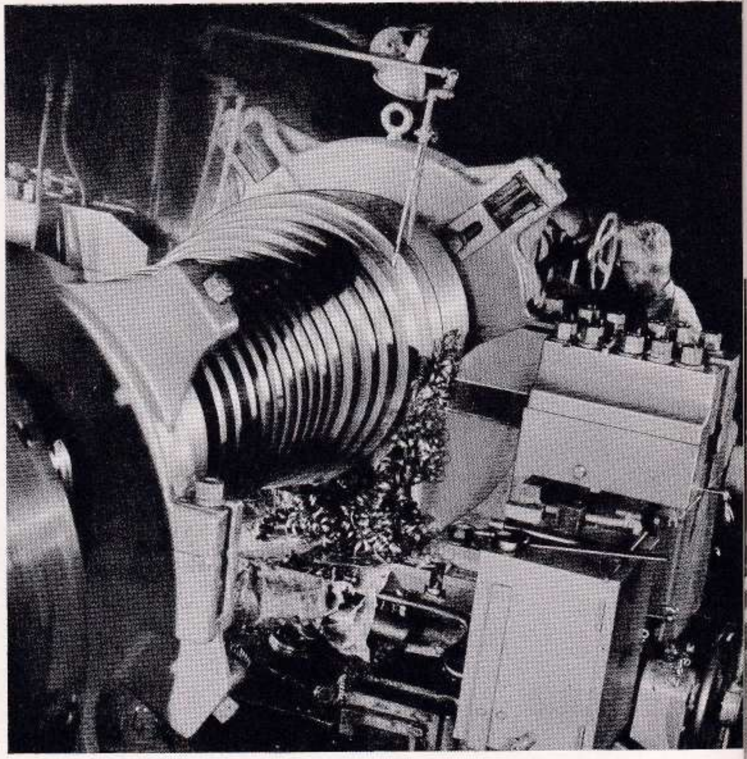
The turbine casing is split along the horizontal center line to provide easy disassembly for scheduled inspections. Piping connections, wherever possible, are made to the lower-half of the casing.

Axial alignment of the turbine and rotating parts is maintained by anchoring the low-pressure end of the turbine to sole plates, and supporting the high-pressure end flexibly, to accommodate the axial expansion which accompanies temperature variations.

Each component of the turbine is produced by people with outstanding skill at their job; from materials which have received numerous and frequent checks for quality; and in many cases from tools designed especially for their task. When you invest in a General Electric turbine-generator, you know you are getting the best.



Magnetic particle test of shaft and solid rotor forgings will reveal any defects in the metal. This test is given to all rotors before and after final machining.



Solid rotor forgings undergo a rough machining after having passed many previous tests to assure high quality.

After final machining all turbine rotors are subjected to a heat stabilization test. This test removes any stresses set up during machining and assures that the rotor will run true when in operation.

2. SPECIAL TURBINE ROTOR TESTS

Since all the mechanical power produced by the steam turbine originates in the turbine rotor, the design, and the materials and manufacturing methods used, and the constant control of quality during manufacture are of extreme importance in the life, efficiency and reliability of the turbine.

The high-quality forgings which G.E. selects for rotor shafts have already received thorough "working" at the forge shop resulting in great refinement of the grain of the metal. Before General Electric accepts a rotor forging, it must have met our standards on ultra-sonic, heat stability, physical and chemical properties, and magnetic particle tests at the forge shop. These tests, as well as others, are repeated in our own factory to assure a sound rotor.

Heat stabilization is one of the most important of these tests. The rotor, after rough machining, is placed in a special lathe and rotated slowly while its temperature is gradually raised in excess of the temperature at which it will operate. The forging is then slowly cooled and indicators track the straightness of the rotor, to make certain that when machined and in actual operation, your rotor will run true. After final machining, the finished shaft is again heated, and if the rotor goes out of shape by more than one-thousandth of an inch, the shaft is not acceptable.

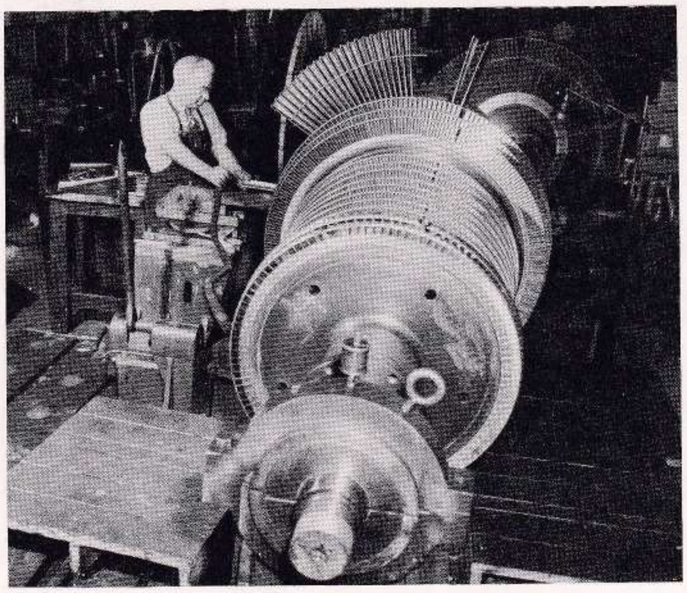
3. PRECISION BALANCE OF WHEELS AND BUCKETS

Either solid or shrunk-on wheel construction is used for G-E turbines. G.E. uses both these rotor designs to provide flexibility in application.

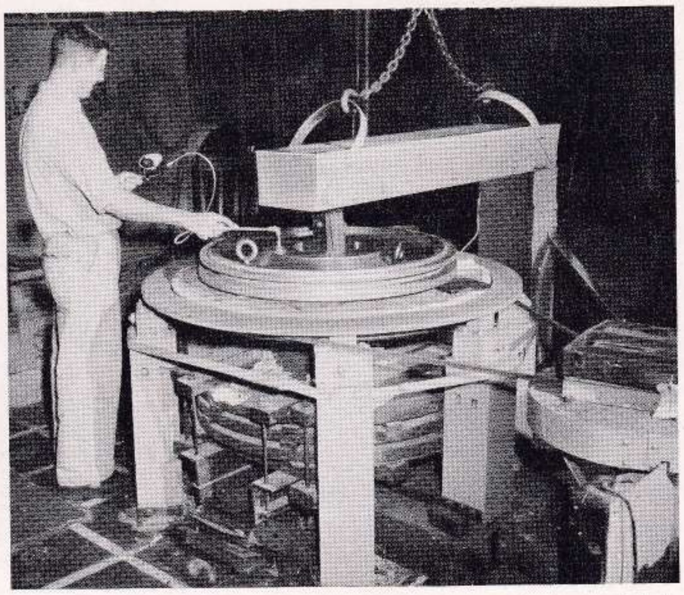
Where shrunk-on rotor construction is used, General Electric selects wheel forgings which have been very thoroughly worked and tested at the forge shop. Test coupons cut from wheel forgings are tested in the laboratory to determine that the forging has the right metallurgical properties to meet General Electric's high specifications.

The wheel is machined, dovetail grooves accurately turned, and the bore carefully ground. After the buckets are assembled on the completed wheel, it is statically balanced before being placed on the turbine shaft. To assemble the wheels, the bore of each wheel is expanded by heating. The wheel is placed on the shaft and spacing gages are used for accurate assembly. As it cools, the wheel firmly grips the shaft. Keys provide additional security.

The form or shape of turbine buckets, the material from which they are made, and the way in which they are fastened in place on the wheel play a great part in the efficiency and life of a turbine.



Turbine buckets being assembled on wheel. After buckets are assembled on wheel shroud, bands are riveted in place.

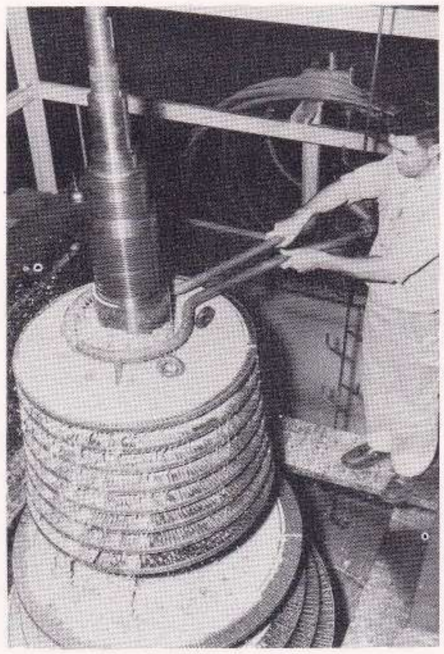


After final machining and balancing the wheel is expanded by heating for shrinking onto the turbine shaft.

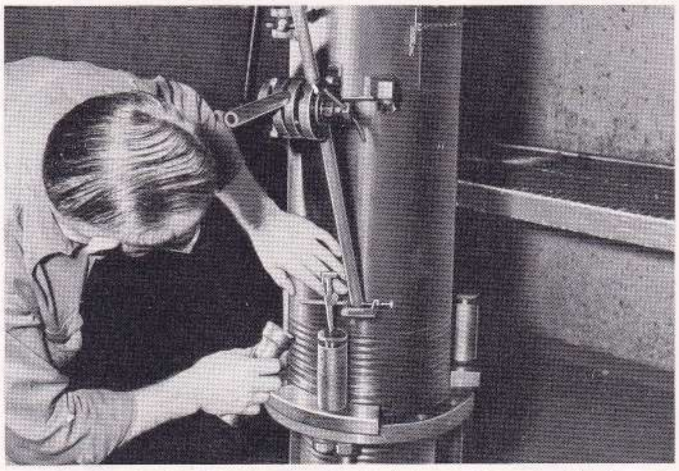
General Electric has carried on a diversified test program for over thirty years, devoted entirely to constantly improving the design of the buckets and the materials from which they are made. This means that General Electric turbines give maximum wheel efficiency consistent with more reliable operation.

Special chrome alloy bar stock, which is particularly resistant to corrosion and erosion by steam, is selected for all turbine buckets. After the stock has been shaped into buckets by the most precise machining, each bucket is given a magnetic particle test which reveals any defects not otherwise visible. Each bucket is then individually inspected, and any defective buckets are immediately rejected.

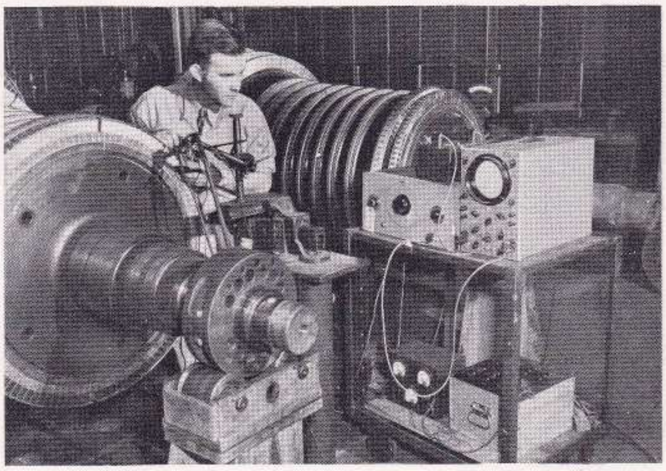
Buckets in the wet steam regions are given a shot peening. This hardens and strengthens the buckets to withstand long wear. After careful weighing, buckets are assembled on the wheels. The dovetail on each bucket is engaged with the dovetail groove on the wheel, to form a secure attachment. Construction of the wheel is completed by enclosing the steam passages with a shroud band which is riveted to the tips of the buckets, giving extra rigidity to the buckets. Because each component of the finished rotor has been carefully balanced — shaft, wheels, and buckets — the assembled rotor usually requires only a minimum of balancing.



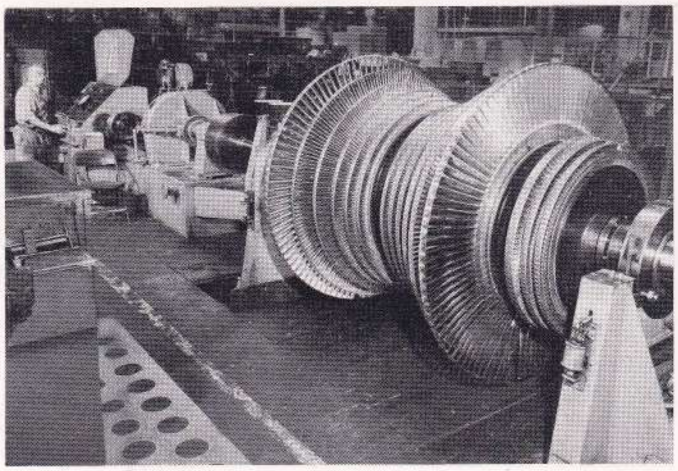
After wheel has been expanded it is lowered into place, positioned, cooled and shrunk onto the shaft.



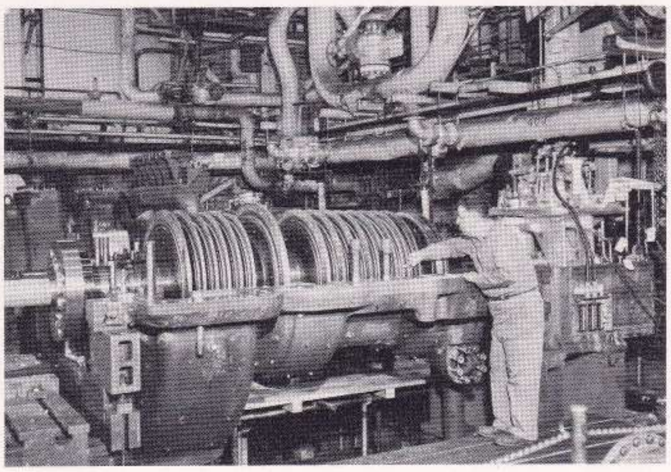
Before each wheel is shrunk onto the shaft its position must be determined with extreme accuracy. Spacing gages are used to position the wheels to within .001 inch.



Buckets are tested for their natural vibration frequency. This natural vibration is then adjusted a safe distance from the turbine's operating frequency to prevent the occurrence of damaging stresses.

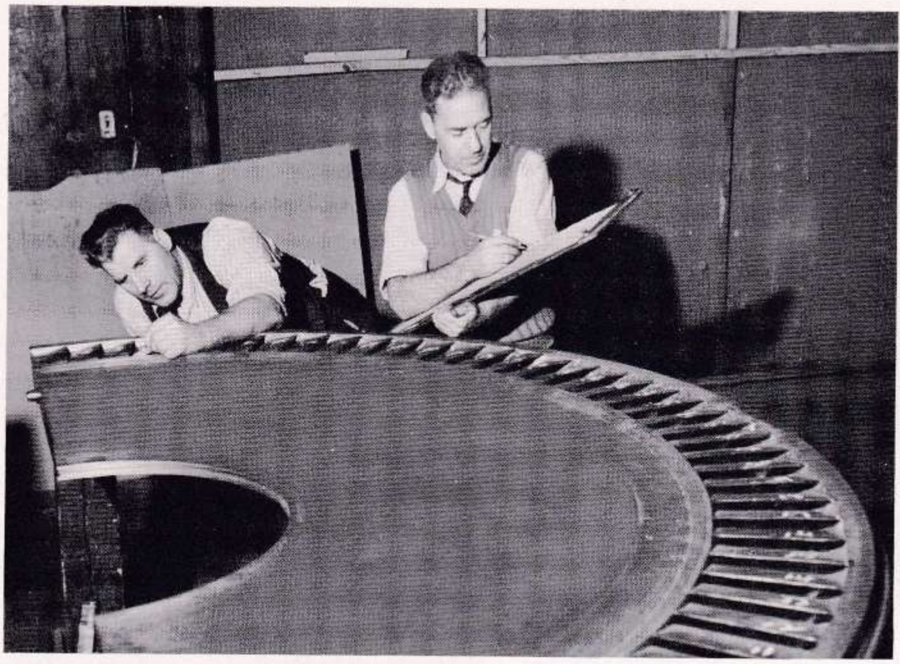


The rotor is given an operating speed run for the final balance test.

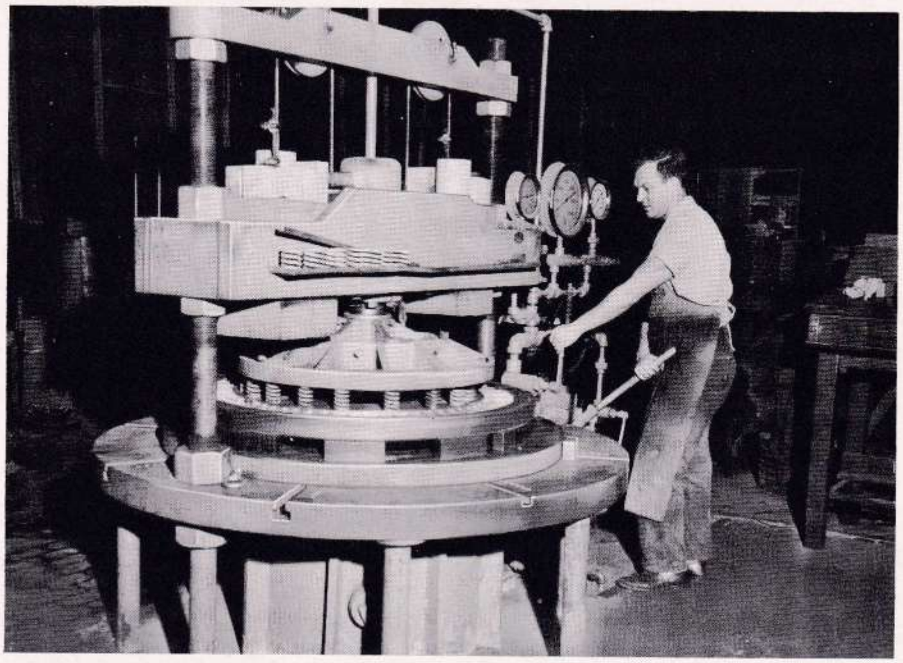


Turbine rotor being assembled in the shell and casing.

4. G-E NOZZLES AND DIAPHRAGMS CONTRIBUTE TO TURBINE STRENGTH AND EFFICIENCY



G-E diaphragms are designed for efficient steam passage. The diaphragm must be built with a specific area and the blades must be set at a precise pitch to assure efficiency.



Diaphragm being subjected to a 200 percent overload pressure test to assure it will withstand operating stresses.

There are many variables which have to be considered in determining the most efficient nozzle areas and the correct angle of discharge from the nozzles into the adjacent buckets; for instance, volume of steam, the speed of the adjacent buckets, and the steam pressure ahead of the diaphragm. General Electric, through continuous research, testing, and developing, is able to design and manufacture, for each turbine, nozzles and diaphragms which best meet all of these considerations and contribute to highest overall turbine efficiency.

In the high-pressure end of the turbine, nozzles are incorporated into the diaphragm by welding.

Chrome-iron alloy is used for all nozzle partitions. After machining, these partitions are assembled in punched bands and welded in position.

Depending upon steam conditions, the outer rings and webs may be either cast iron or cast steel. In the low-pressure section of a turbine, the nozzles are cast-in. In this process the nozzles become an integral part of the cast diaphragm.

The rigid construction and constant quality-control checks of the nozzles and diaphragms during manufacture result in accurately shaped and sized nozzle passages, which are essential to turbine efficiency.

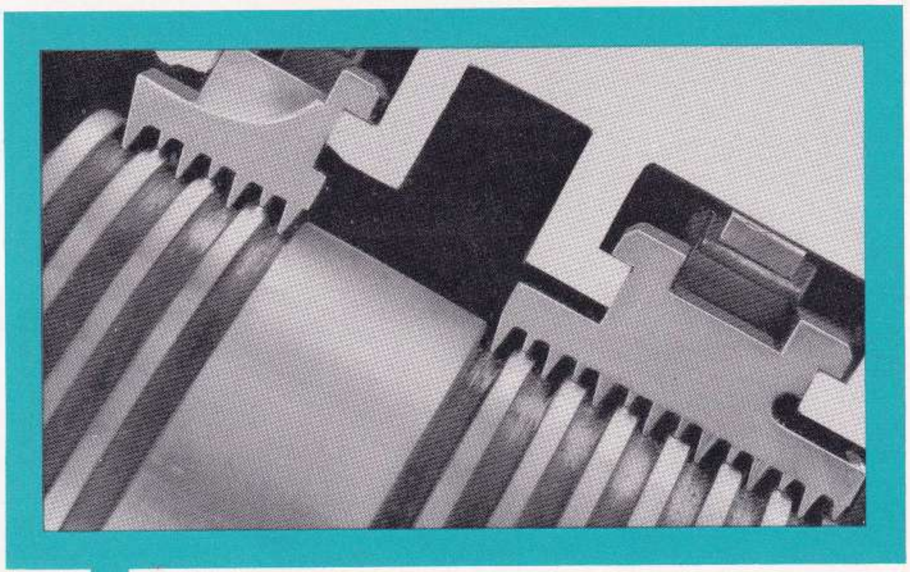
Here are some other manufacturing and assembly procedures which help add to turbine efficiency: Sample nozzle diaphragms are tested periodically. These nozzle diaphragms are submitted to an over-pressure test of approximately 200 percent normal operating pressure, to assure operating reliability.

The diaphragms, when assembled in the turbine, are supported at the centerline of the turbine casing on adjustable screws, so that shaft clearances are maintained during temperature changes. This is important in maintaining turbine efficiency.

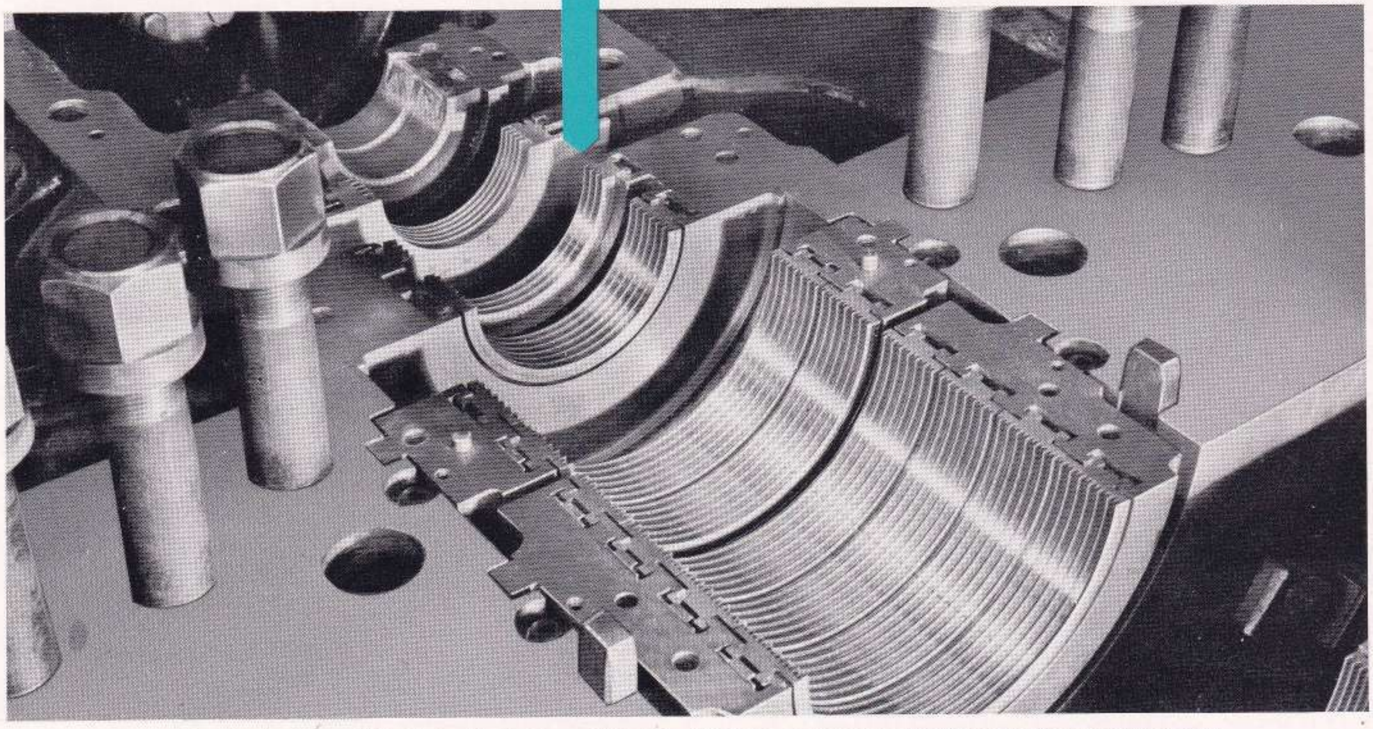
5. METALLIC LABYRINTH PACKING ASSURES TIGHT STEAM SEAL

Packing in General Electric turbines is of the metallic labyrinth type, spring-backed from the diaphragm (and the casing, where the shaft passes through the casing). The seal edges face toward the shaft. The packings are made from special alloys, designed to operate in very close proximity to the shaft, maintaining the required seal, without causing any damage to the packing or the shaft. Tooth construction is almost exclusively of the high-low type, with the high tooth projecting into a groove in the shaft, and the low tooth extremely close to the shaft surface. This arrangement offers a maximum protection against steam leakage and resultant loss of energy.

High-low construction of the teeth, plus spring-backing of the packing results in sustained efficiency, since this type of packing is much less sensitive to variations in clearances than non-step-tooth packings.

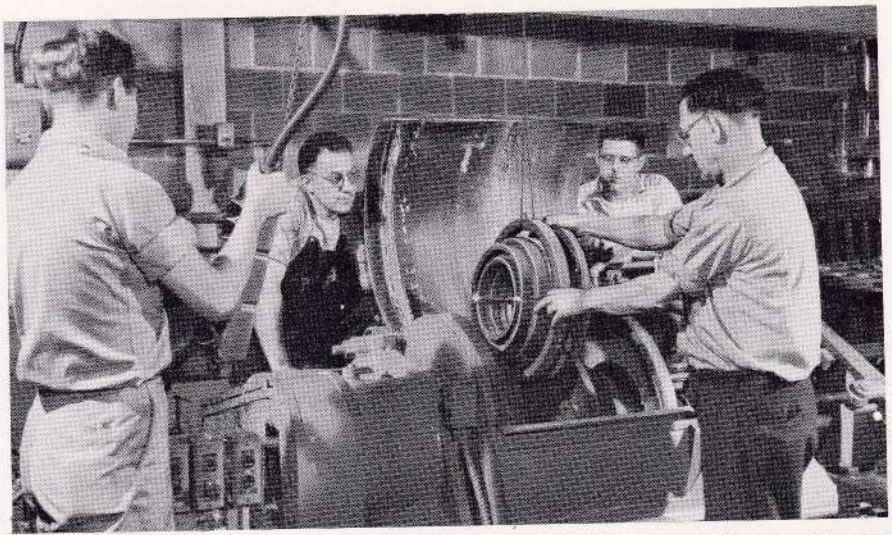


Steam seal at shaft helps prevent steam leakage or air infiltration where shaft passes through turbine casing.

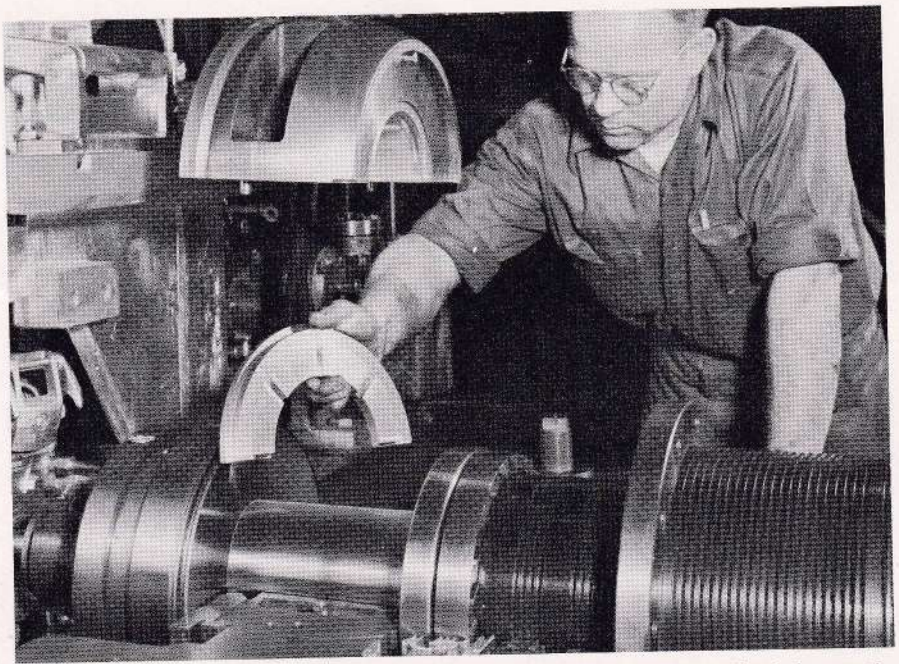


Packing in the General Electric turbine is the metallic labyrinth type, spring supported from the diaphragm or casing.

6. BEARINGS BUILT FOR TOTAL TURBINE LIFE



Bearings are made of the highest quality babbit and as shown here are centrifugally cast onto a steel backing.



Dovetails are machined into the backing of the thrust bearings to provide a mechanical connection between the babbit and steel.

The journal bearings of each turbine are specially designed to provide long, more reliable operation. The bearings are constructed with spherical seatings. This allows easy alignment of the unit. The bearings are made of the highest quality babbitt centrifugally cast onto a steel backing. The babbitt is bonded to the backing assuring the best possible adhesion.

The General Electric tapered-land-thrust bearings provide short axial length, low mechanical losses, high load carrying ability, simplicity and a solid steel backing.

7. LUBRICATION OIL SYSTEM

The G-E lubricating oil system is designed to provide the oil required to assure long, highly dependable unit operation with a minimum of maintenance.

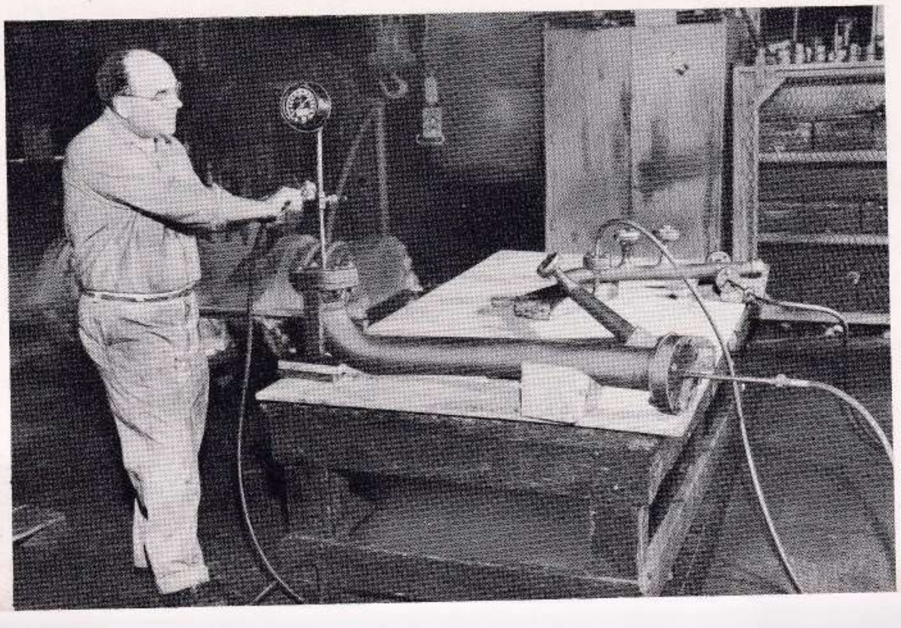
The lubricating oil for the operating unit is provided by a shaft driven lube oil pump. During starting and stopping, a steam driven auxiliary pump furnishes the necessary oil. In addition a motor-driven pump can be provided if required.

The pump for the lubricating system is enclosed in the oil tank. The tank is designed to allow a minimum downward movement of the oil so that the air will detrain and any water will settle. The tank is also coated with a corrosion resistant material to help assure long life.

In high temperature areas the lubricating oil passes through pipe lines which are enclosed in the drain lines. This reduces the possibility of high pressure oil coming in contact with high temperature metal.

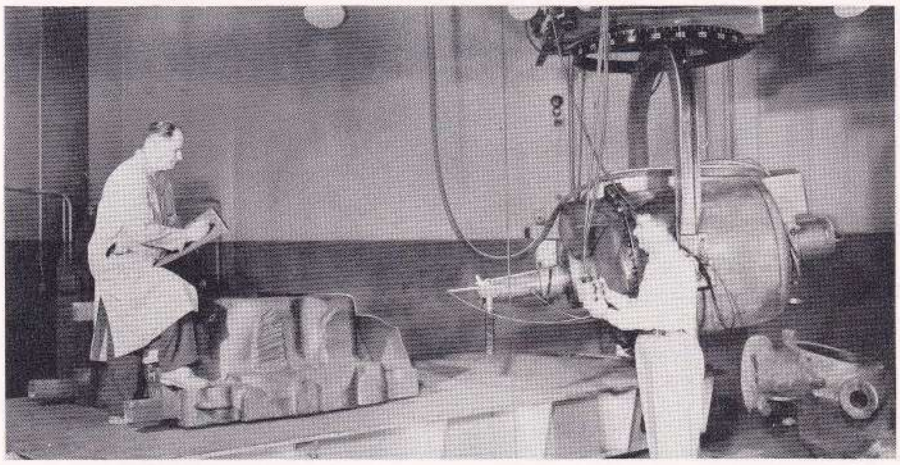
The drain lines are sloped to the oil tank to help assure smooth drainage and are also designed to help prevent entraining air.

The lubricating oil system is designed to provide the oil required to assure long, more dependable unit operation with a minimum of maintenance.



High pressure oil piping is subjected to a hydrostatic test to detect possible flaws.

8. STRONG CASINGS TO WITHSTAND HIGH PRESSURE, TEMPERATURES



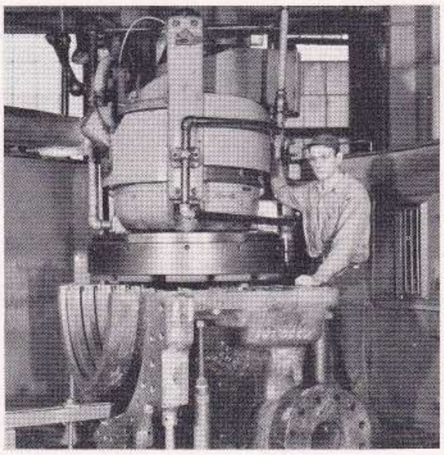
The turbine's high pressure casing is subjected to an X-ray test to detect possible internal flaws.

With the growing trend to increases in steam pressures and temperatures, high quality steel castings are needed to insure safety and reliability. General Electric subjects the steel castings for its turbines to a series of X-ray, magnetic particle and hydrostatic tests at the foundry and at the factory.

In addition, the design of the casing helps assure reliability and efficiency of the turbine over the life of the unit. Separation of the high pressure-temperature nozzle area from the casing walls, flexible expansion bend, minimum diameters and lengths, stepped flange thicknesses, large fillets, tapered thread bolting, double casing construction for extremely high pressures and temperatures and inwardly turned steam chest flanges all contribute to the maintenance of design clearances and a minimum of distortion. These features all help assure the high efficiency, long life, and minimum maintenance of General Electric casings.

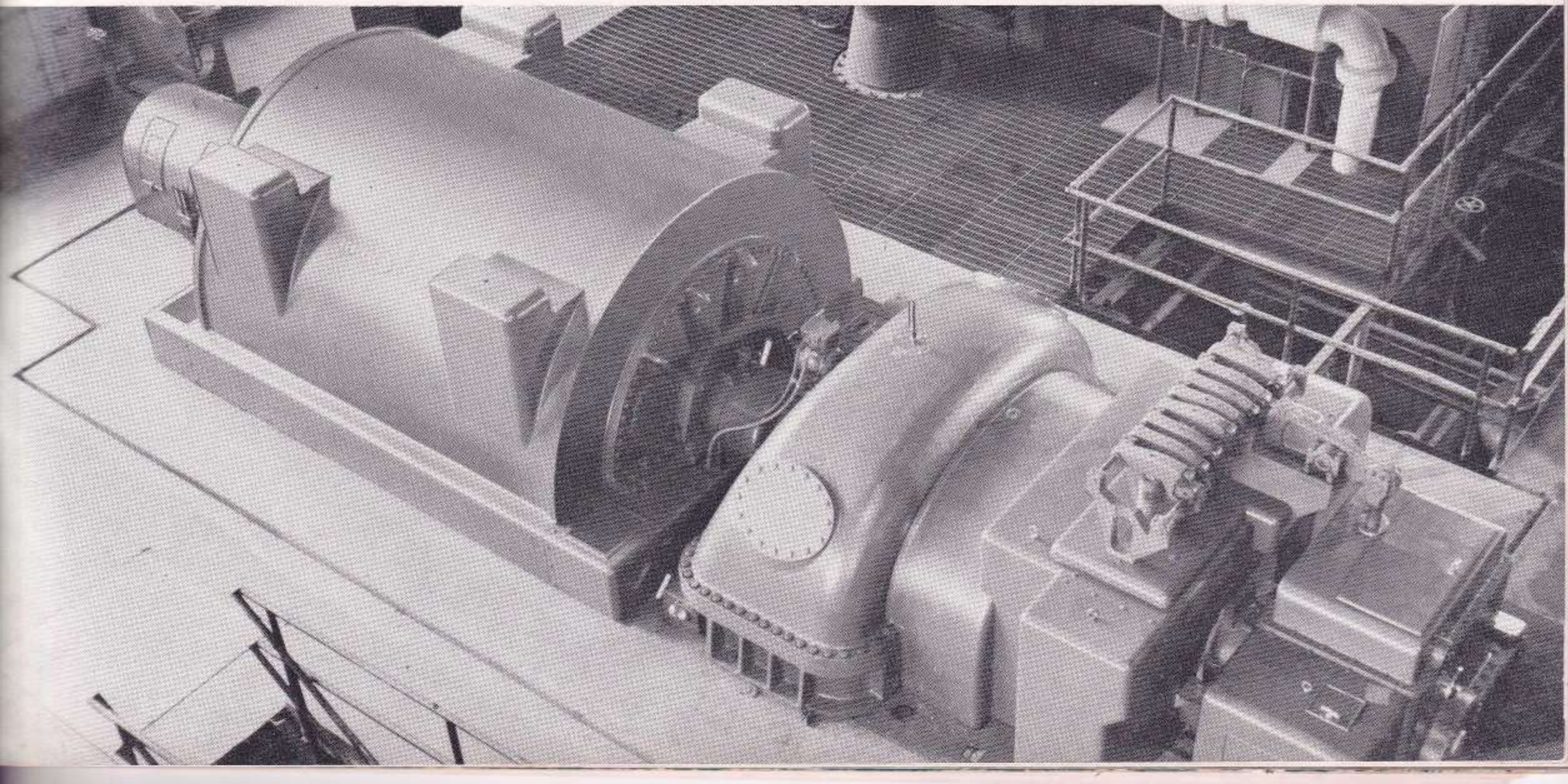
9. EXHAUST CASINGS

To assure a minimum of maintenance, the exhaust casings are subject to tests similar to those for the high pressure casings. The design of the exhaust casings include features to help prevent misalignment, to minimize thermal stresses, to help protect oil piping, to continuously drain water in the moisture region, to provide steam for feedwater heating pressures, to provide ample emergency protective relief pressure. A steam-tight horizontal joint is assured by machining the joints on a special grinding machine. In addition, the generous exhaust area gives the ultimate efficiency for the exhaust steam conditions.

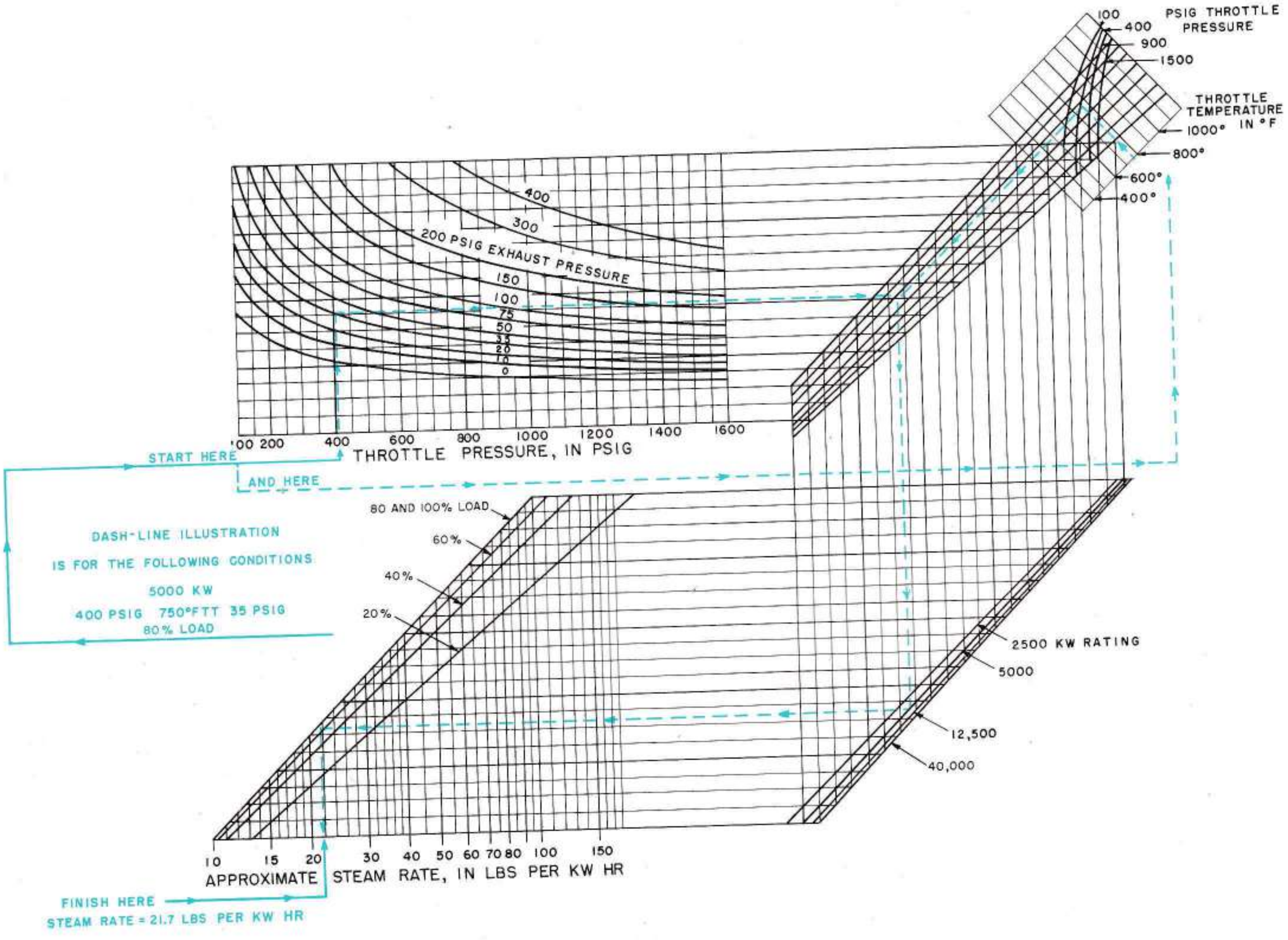


A special grinding machine is used to make the horizontal joints steam-tight.

General Electric turbine-generators fit a wide variety of applications. This 15,000-kw unit is producing power for a steel company.

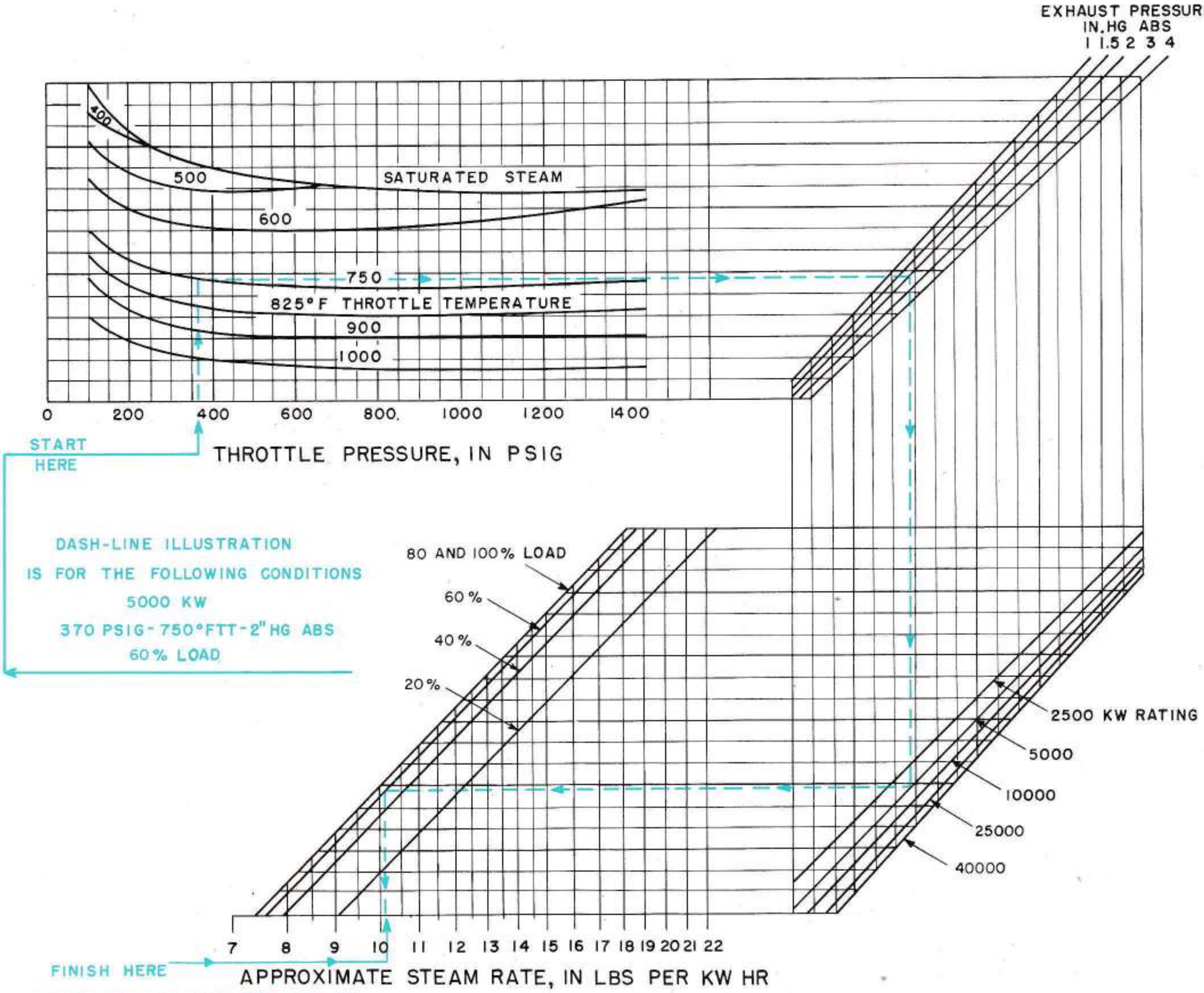


APPROXIMATE STEAM RATES FOR NONCONDENSING TURBINES



The steam rates resulting from these graphs are approximate and should be used for estimating purposes only. The examples shown for the 5000 kilowatt noncondensing and 5000 kilowatt condensing turbines illustrate the method for calculating the steam rate for any particular unit. Kilowatt ratings are maximum rated capacities. For steam conditions not covered by these curves refer to your local General Electric Apparatus Sales Office.

APPROXIMATE STEAM RATES FOR CONDENSING TURBINES



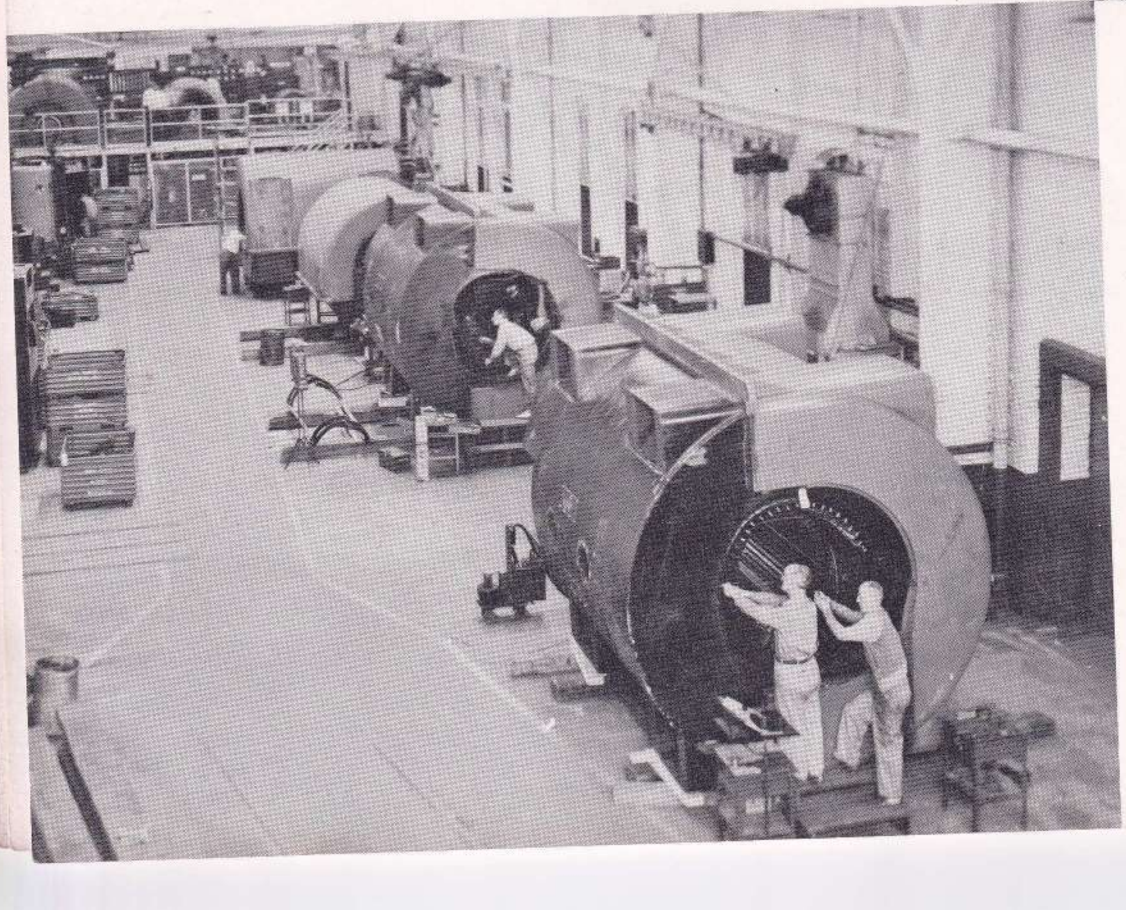
START HERE

DASH-LINE ILLUSTRATION
IS FOR THE FOLLOWING CONDITIONS
5000 KW
370 PSIG - 750°FTT - 2" HG ABS
60% LOAD

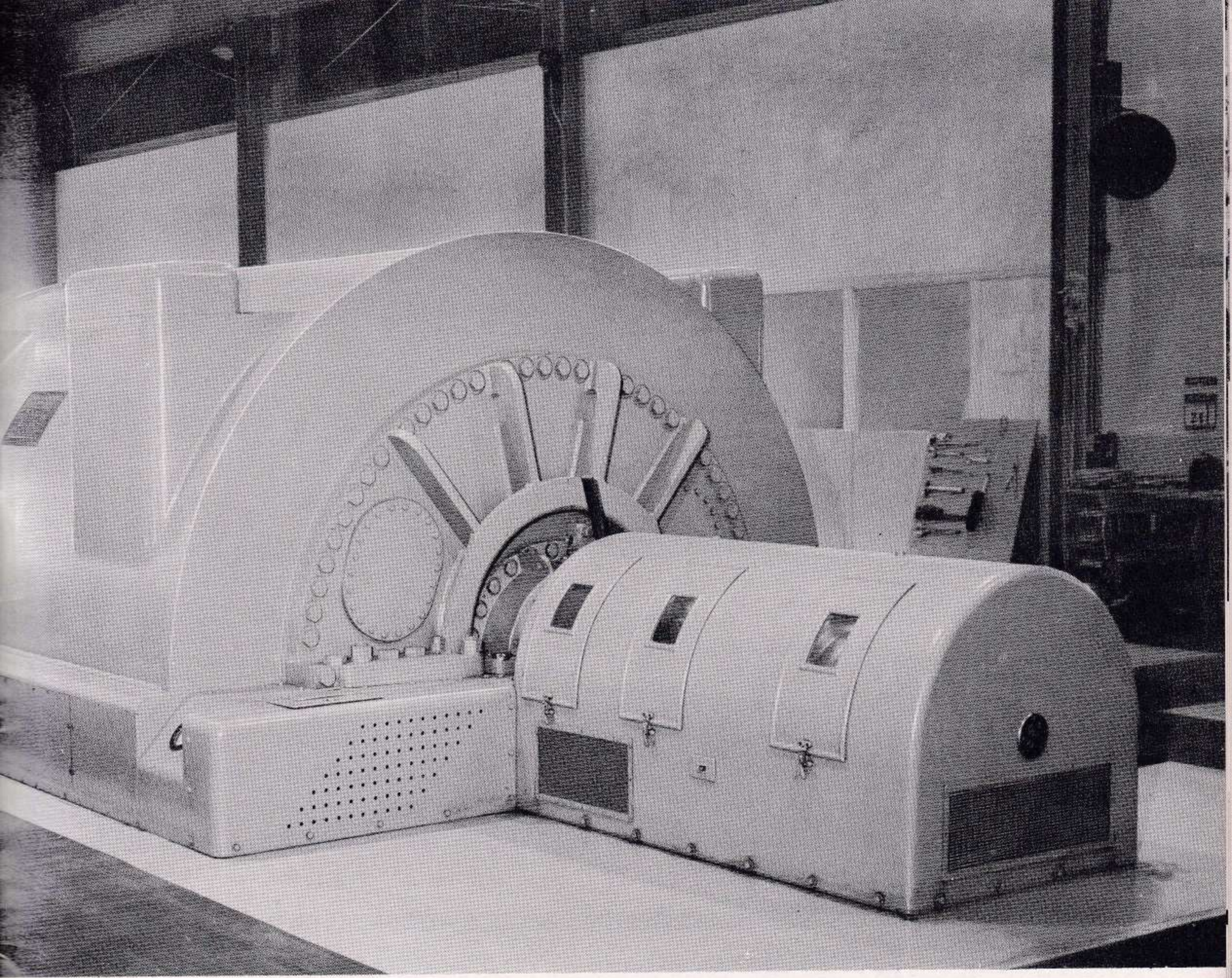
FINISH HERE

STEAM RATE = 10.1 LBS PER KW HR

G-E Design and Manufacturing Features Which Assure Generator Efficiency and Reliability



Precision manufacturing helps make Gener
Electric generators the best available. He
generator coils are being assembled in stat
frames at the Lynn River Works generator ba

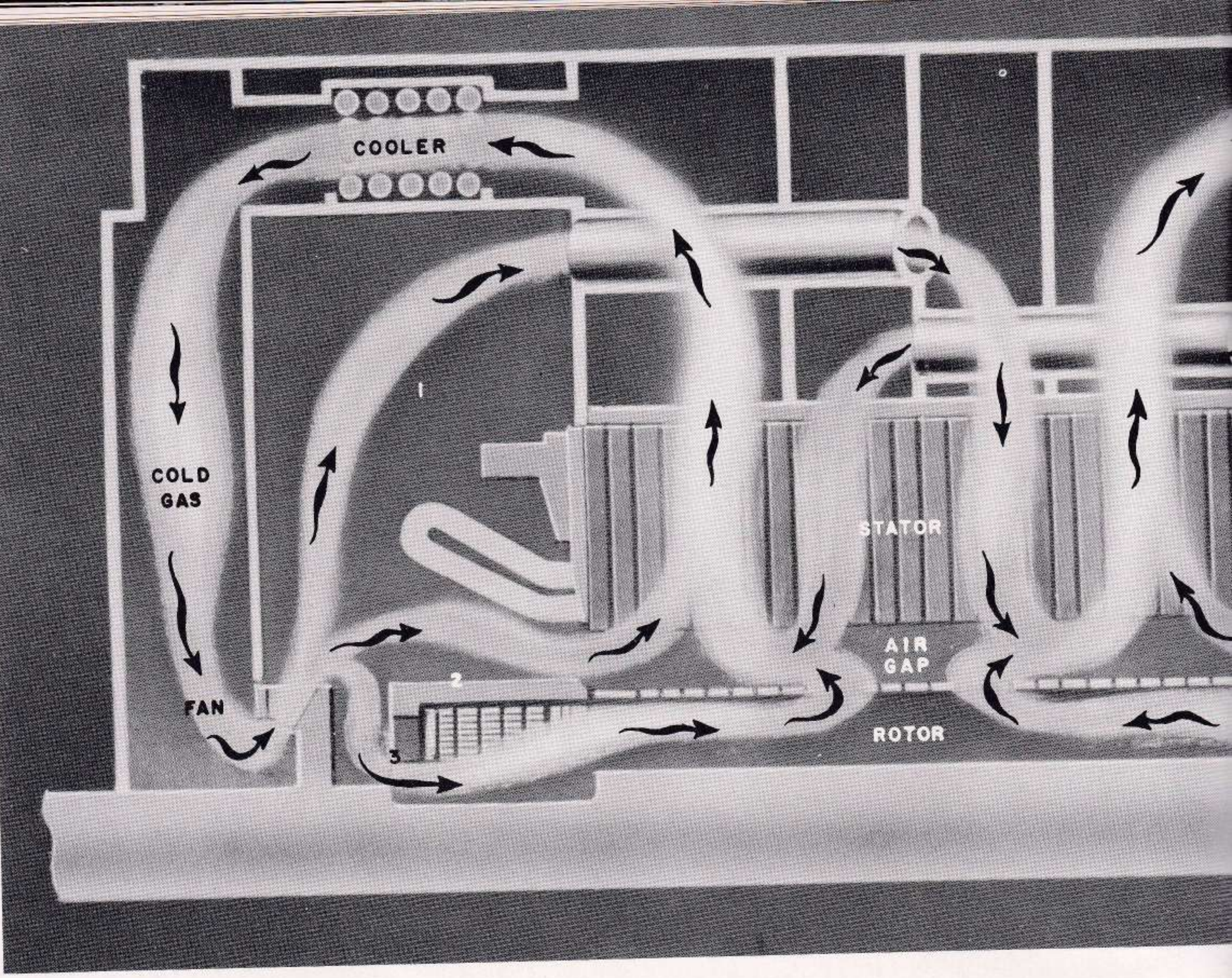


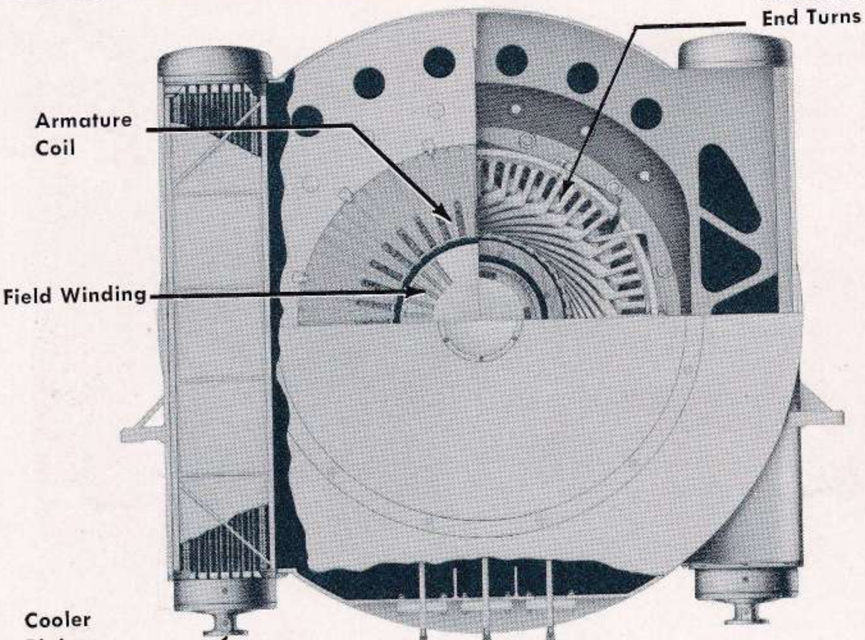
Years of research, design, testing and manufacturing experience enable General Electric to build generators with efficiencies approaching 99 percent. This turbine-generator is producing power for a utility.

General Electric generators are designed to provide a more reliable and efficient source of power. Maintenance during the life of the unit is kept to a minimum by the use of high quality material, careful construction and precise testing during manufacturing. Years of experience in designing, manufacturing and testing have enabled General Electric to build generators with efficiencies approaching 99 percent.

Valuable data obtained from the continued testing of each unit is used to improve generator design. Improved materials are continually explored and new manufacturing methods are evolved to improve generator performance. Skilled factory craftsmanship and engineering leadership combine to give you the most for your generator dollar.

The following pages detail a few of the features of General Electric generators which help to make these units more reliable, efficient and easy to maintain.





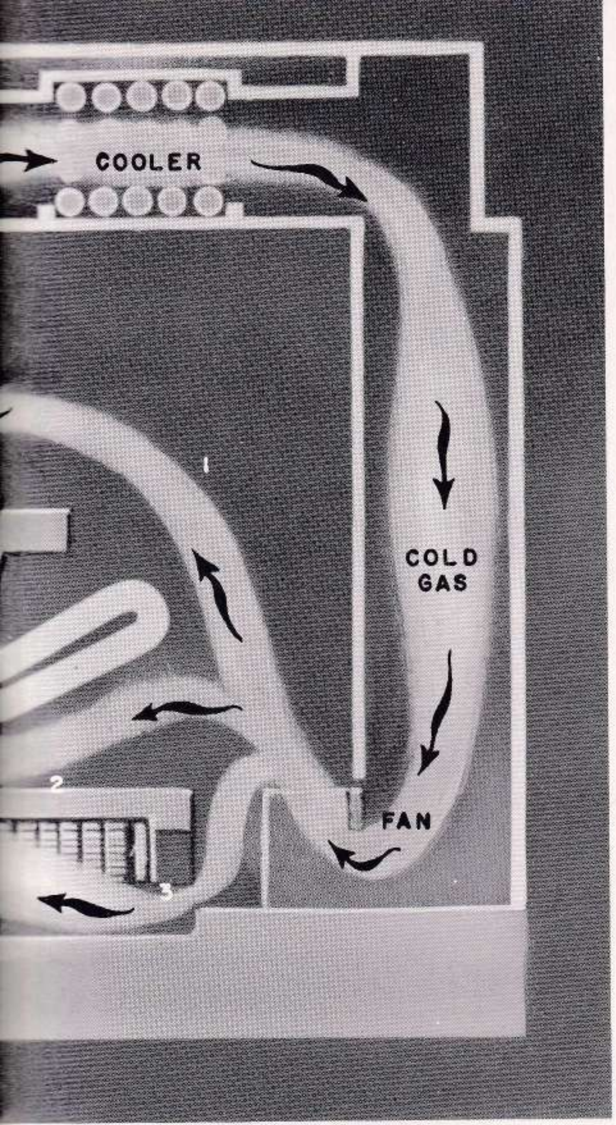
End view cutaway of generator showing corner cooler posts.

AIR-COOLED GENERATORS

The field and armature of the smaller rated generators are cooled by air. One vertical cooler is located in each one of the four corners on the standard generator.

The generator frame is constructed of a steel wrapper plate with internal bracings to provide a rigid structure. Vibration is kept to a minimum by accurate balance and tuning of the generator frame. The airtight frame helps keep the generator clean and contributes to lowering its noise level.

The water connections are placed at the bottom. This design eliminates unsightly external water connections and makes it possible to remove a cooler through the top of the cooler post while the generator is operating. Even with one cooler section out of service the generator can produce 70-80 percent of its kva rating and the water flow to the other coolers will remain the same.



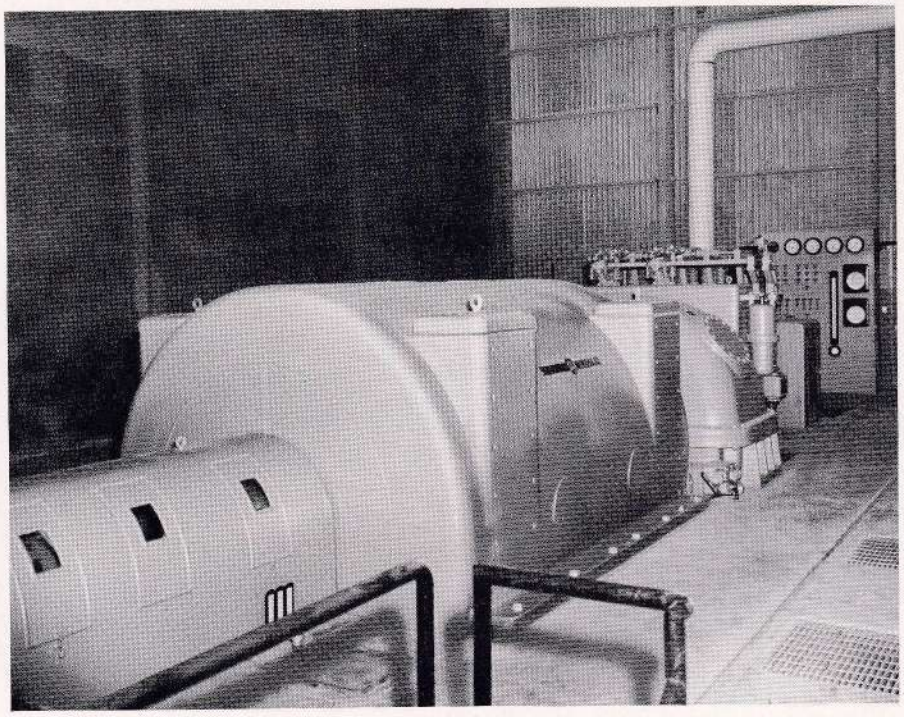
G. E.'s Ventilation System Assures Uniform Cooling of Entire Generator

Three-path ventilation system for uniform cooling of the entire generator is shown on this diagram. Fans mounted at each end of the generator rotor force the cooling gas into three internal paths:

1. **Over the stator end-turns** to passages between the core and wrapper plate, then radially inward through ducts in the laminations to the air gap, and radially outward through adjacent cooling ducts in the core.

2. **Over the stator and rotor surfaces** of the air gap and radially outward through cooling passages of the stator core.

3. **Over the rotor end windings,** through internal ventilating ducts of the rotor to the air gap, and through the discharge passages of the stator core.



General Electric builds both air and hydrogen cooled generators. Both ventilation systems are designed to provide uniform cooling.

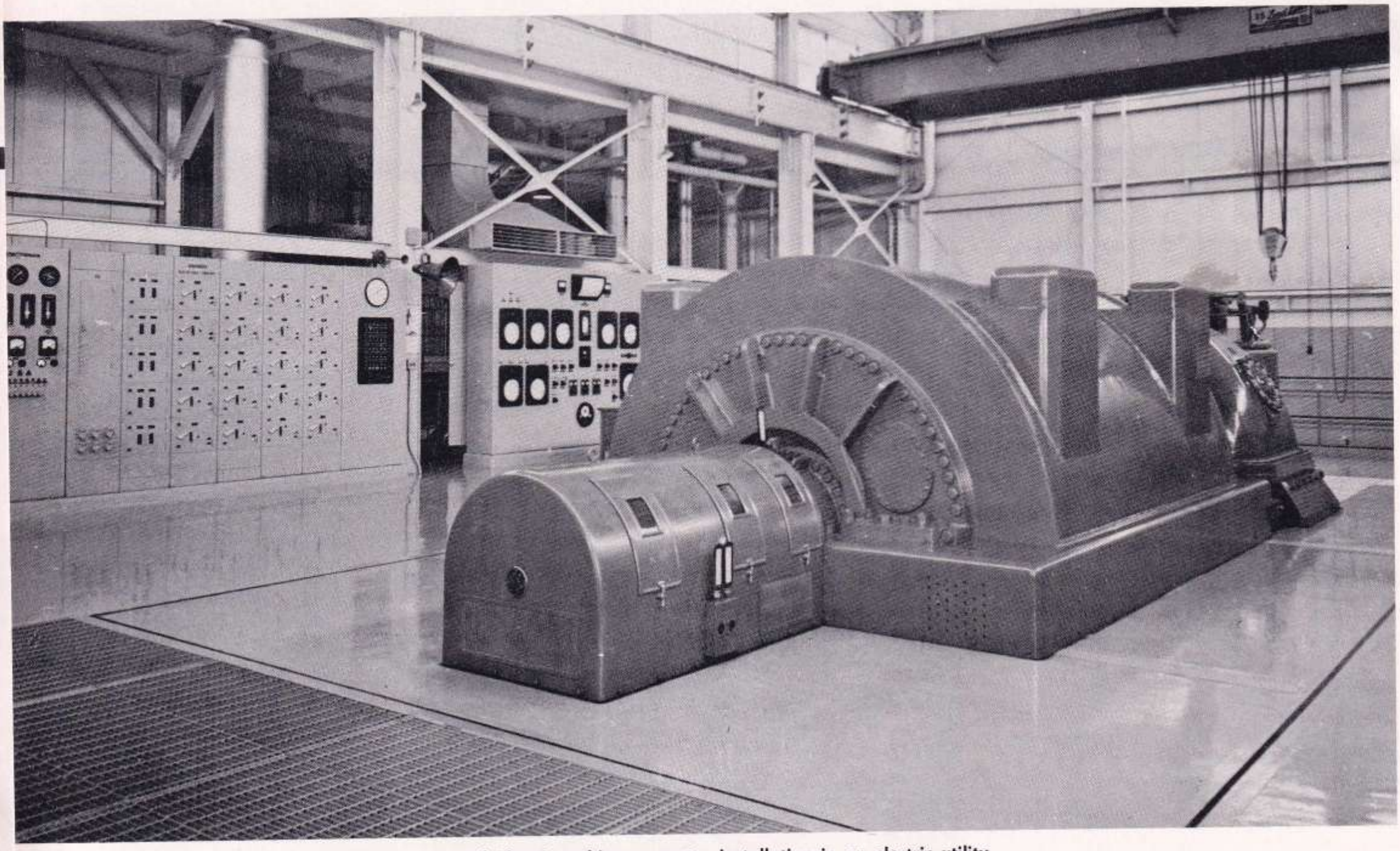
G-E HYDROGEN COOLING SYSTEM OFFERS . . .

1. **Increased efficiency**
2. **Lower windage losses**
3. **Cleaner ventilating passages**
4. **Minimum corona effect**
5. **Low hydrogen consumption**
6. **Increased safety and reliability**

On General Electric turbine-generators in the size range of 16,500 to 40,000 kilowatts, hydrogen cooling can provide full load efficiency from one-half to one percent better than air-cooled machines of equivalent ratings. This can mean substantial annual fuel savings for users of units in this size range.

Because the density of hydrogen is only about one-fourteenth that of air at a given temperature and pressure, the use of hydrogen results in much lower generator windage losses. In addition to improving efficiency, this contributes to a lower noise level for hydrogen cooled generators.

The corona effect is negligible and the armature insulation retains its flexibility for a longer period of time because the windings are enveloped in a hydrogen atmosphere. Enclosed construction keeps out dirt and moisture, with the result that ventilating passages are cleaner. Hydrogen cooling is safer since commercially pure hydrogen will not support combustion.



General Electric turbine-generator installation in an electric utility.

In many installations, the superior heat transfer of hydrogen cooling is particularly advantageous in that it allows smaller generator size and weight and reduces the amount of cooling water required.

HIGH PURITY, LOW CONSUMPTION

The General Electric system maintains high hydrogen purity with the consumption of hydrogen kept to about 50 percent of other systems now in use. On many General Electric generators, casing gas purity has been maintained above 99 percent with hydrogen consumption as low as 35 cubic feet per day when operating at 15 pounds pressure.

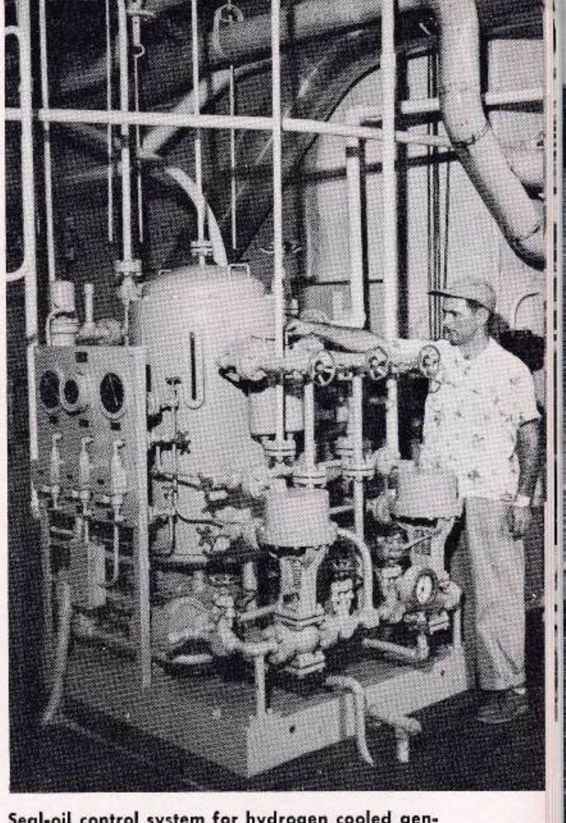
G-E turbine-generators are able to achieve this performance through the combination of several important design features in the hydrogen system:

A seal assembly at each end of the generator prevents the escape of hydrogen from the casing along the rotor shaft. The seal, which is supported from the outer end shield, consists of a pair of bronze sealing rings with an internal diameter just a few thousandths of an inch larger than the shaft diameter. Oil, at a pressure about five psi above the hydrogen pressure in the casing, is supplied to the seal housing and enters the annular space between the sealing rings. It flows in both directions between the sealing rings and the shaft, preventing the loss of gas. The bearing is entirely external and separated from the shaft seal and may be inspected without removing the gas from the generator.

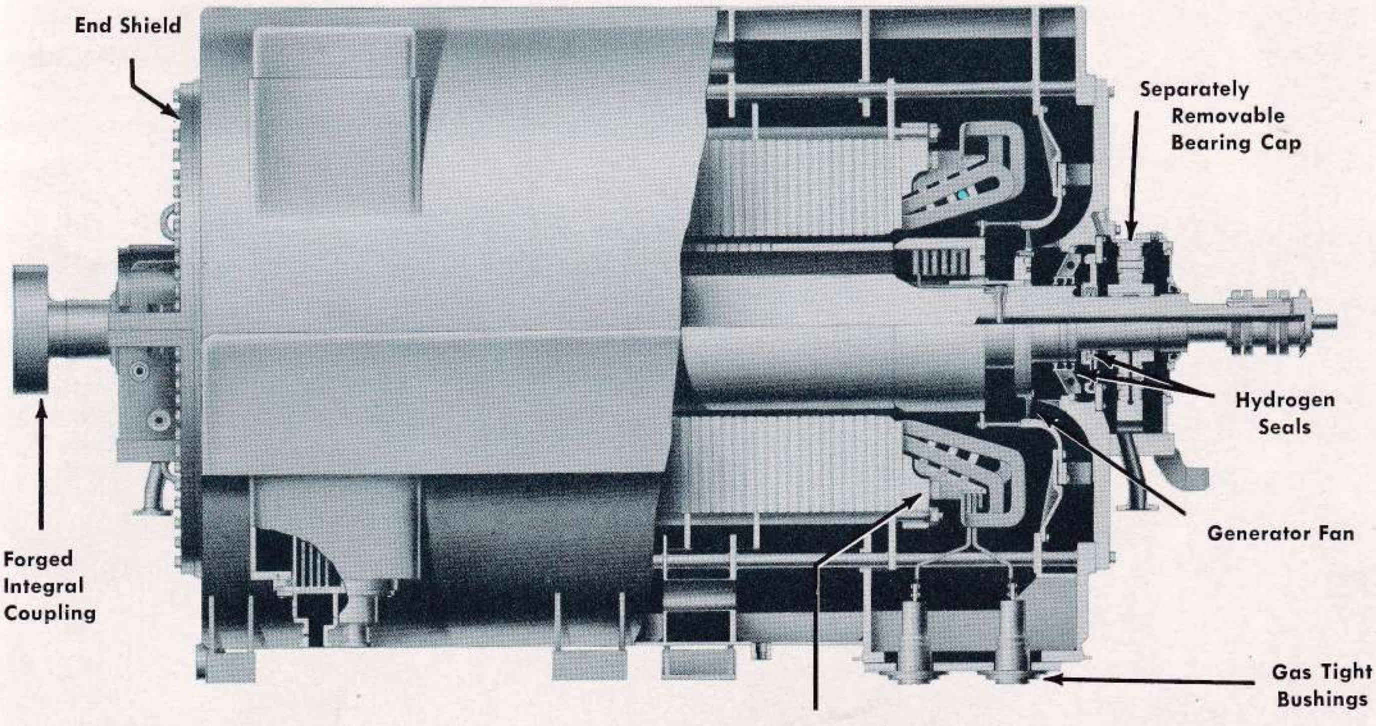
Further, a **seal oil system** constantly and automatically frees the oil of entrained air and gas as it returns from the generator. This separated air and gas is vented to the atmosphere.

A gas control system feeds hydrogen into the generator at 99.6 percent purity after the system has been purged of air by CO_2. Moisture is removed from casing gas by a gas dryer. To help prevent contamination of casing gas with air, a small constant flow of hydrogen is continuously scavenged to atmosphere through monitoring flow meters and analyzers.

Finally, nine automatic protective devices give the operator immediate warning of any unusual mechanical or operational condition.



Seal-oil control system for hydrogen cooled generator. The seal oil prevents the escape of hydrogen from the generator and the entry of air.



Cutaway view of hydrogen-cooled generator.

HOW GENERAL ELECTRIC GENERATORS EARN THEIR REPUTATION FOR EFFICIENT PERFORMANCE, RELIABILITY

The accepted rotor forging is given an ultrasonic test to detect small flaws which might be present deep within the forging.

1. QUALITY BEGINS IN THE ROTOR FORGING

Each rotor forging is tested for tensile, yield and impact strength at the forge shop. These tests are repeated at the factory to ensure that the rotor will meet the high General Electric standards.

The accepted rotor forging is first rough machined and then given an ultrasonic test. This test detects any small flaws that might be present deep within the forging.

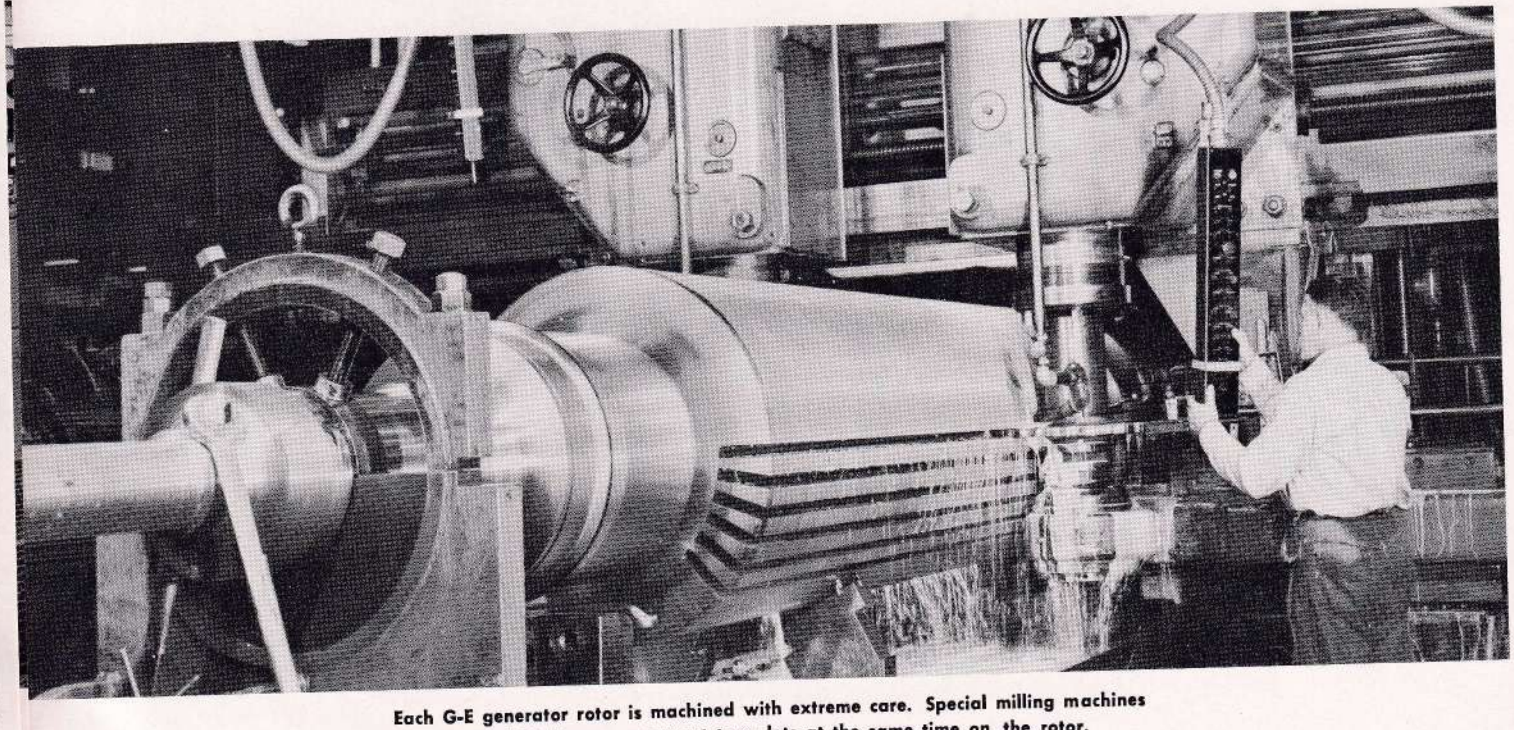
These careful tests are vital because each rotor must support loads of many millions of pounds.

2. WHY PRECISION MANUFACTURING IS ESSENTIAL

The combination of large rotor sizes and high speeds makes it essential that the rotor be machined with the utmost care. The pole faces, journals, integral flanged coupling, and collector rings must be concentric to minimize vibration and noise.

Proper cutting of the slots for the field windings contributes to the balance of the rotor. Special milling machines with cutters 180 degrees apart on the rotor are used to cut two slots at the same time. After each cut the rotor is turned so that adjacent slots will be milled by alternate cutters. This equalizes any unbalance effect which might be caused by any difference in wear of the cutters.

A magnaflux test is then made on the completely exposed surface of the rotor. The purpose of this test is to discover any surface flaws on the rotor. Thus through the ultrasonic and magnaflux tests any flaws in the rotor are detected before the manufacturing process advances any further.



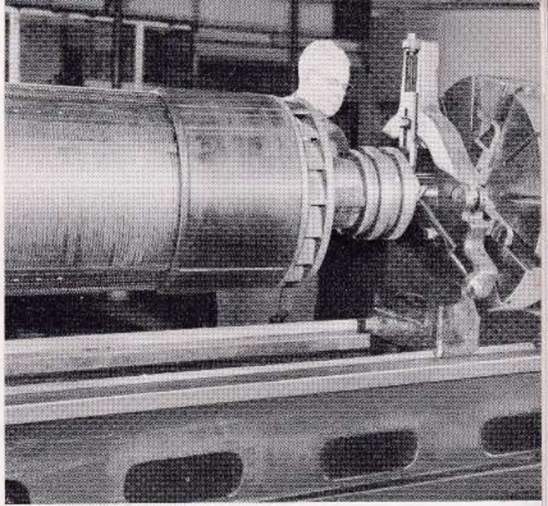
Each G-E generator rotor is machined with extreme care. Special milling machines with cutters 180 degrees apart cut two slots at the same time on the rotor.

3. CAREFUL MACHINING OF COLLECTOR RINGS

The collector rings are the electric connection between the generator field and exciter. Carefully machined forged steel rings are shrunk on over a one-piece, molded-mica sleeve. The mica sleeve serves to insulate both the collector rings and the collector leads from the rotor shaft. The assembled collector is then shrunk onto the generator shaft and the collector leads are silver brazed to the collector rings. This assembly provides maximum reliability for this vital link in the generator construction.

Helical grooves are cut into the face of the collector rings. These grooves help keep dust and dirt from getting between the collector rings and the carbon brushes which come in contact with them. This feature adds to the reliability of the unit and lowers maintenance expense.

A fabricated steel enclosure, extending from the generator end shield to the exciter, adds to the protection of the collector against dust and corrosive atmosphere, and completes the exciter and collector ventilation circuit.



The collector is assembled by skilled craftsmen and then shrunk on the generator shaft.

4. MORE RELIABLE WINDING INSULATION FOR LONG LIFE

The generator insulation makes up only about one percent of the generator's weight, but the slightest flaw in the insulation could cause a failure of the whole unit. This means the highest quality insulating material must be used and the greatest of care must be taken in applying it to the field and armature.

General Electric uses mica formed into tape, plus other inorganic material such as glass and asbestos as insulation. Mica has an extremely high resistance to the flow of electricity, high dielectric strength and high resistance to thermal aging and corona.

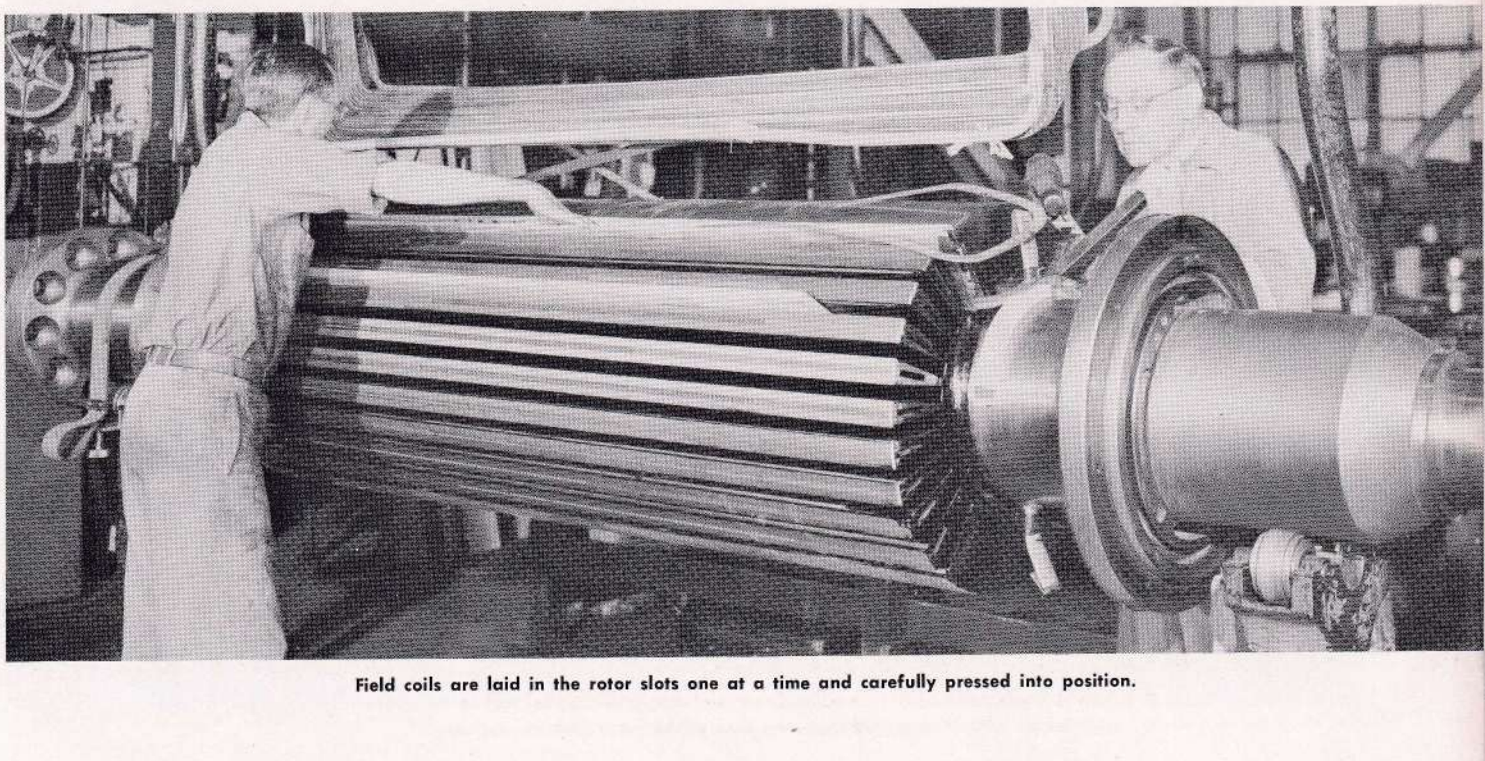
The rotor windings that carry the field current are formed on special winding machines from heavy rectangular silver-bearing, copper alloy. This special alloy is used to help prevent breakage of the turns under prolonged stress and high temperature. After forming, the coils are annealed. This relieves the stiffness at the turns and allows the coils to fit easily into the rotor slots and lie flat. All foreign material and sharp edges are removed from the windings to help prevent any insulation damage.

To insulate the field coils from the core, the rotor slots are lined with a heavy slot armor molded from mica and glass. The coils are then laid in the slots, one turn at a time, and carefully pressed into position, to prevent any kinks or bends in the top turns during operation. The windings are held in the slots by metal wedges and the end turns held in position axially by special blocks. The assembly is then given short-circuit and high potential tests at 3500 volts a-c.

The field is then baked for several days at a temperature much higher than it will be subjected to during actual operation. The baking process drives out any solvents or moisture in the field which would shorten insulation life.

The end turns of the windings are held in place by retaining rings shrunk on centering rings. The retaining rings are of high quality steel. They are given extensive strength tests and a fluorescent penetrant test to detect surface flaws. Non-magnetic retaining rings are used to reduce the size and weight of the generator and to reduce end heating effects at leading power factors.

Fans, mounted at each end of the rotor, circulate the cooling medium (air or hydrogen) throughout the generator and coolers.



Field coils are laid in the rotor slots one at a time and carefully pressed into position.

Grain-oriented strip steel, used for stator punchings, is cut from steel in a manner designed to reduce losses and improve current flow.

5. ORIENTED-GRAIN STRIP STEEL REDUCES CORE LOSS

It is now possible to build units with both greater efficiency and higher ratings without increasing the generator size, by the use of oriented-grain strip steel for the stator punchings.

Core losses have been reduced by about 30 percent and the exciting current for the stator core iron by more than 50 percent through the use of this steel. It is also possible to reduce core losses and lower field current on existing sizes by the use of oriented-grain strip steel. Oriented-grain strip steel has a unique grain size and grain alignment which result in reduced losses and improved magnetizing properties when magnetic flux flows parallel to the grain direction. These stator punchings are cut from the steel in such a manner that the core flux will flow in the best direction for low losses and exciting current.

The generator stator core consists of thousands of thin silicon-steel laminations insulated from each other and tightly compressed between heavy clamping flanges. The stator windings are inserted into open slots in this core and are held tightly in place with wedges. The wedges will stay tight despite the varying conditions of heat and moisture which occur in service.

To insulate the stator punchings from each other, General Electric developed a baking enamel containing silica, which provides excellent insulation in normal service. This enamel retains its excellent insulating properties even when subjected to extreme heat.

6. ARMATURE WINDINGS DESIGNED TO CARRY HEAVY LOADS

To assure maximum life for the armature windings — which carry larger currents than the rotor windings and must therefore be of a larger size — the following processes are used:

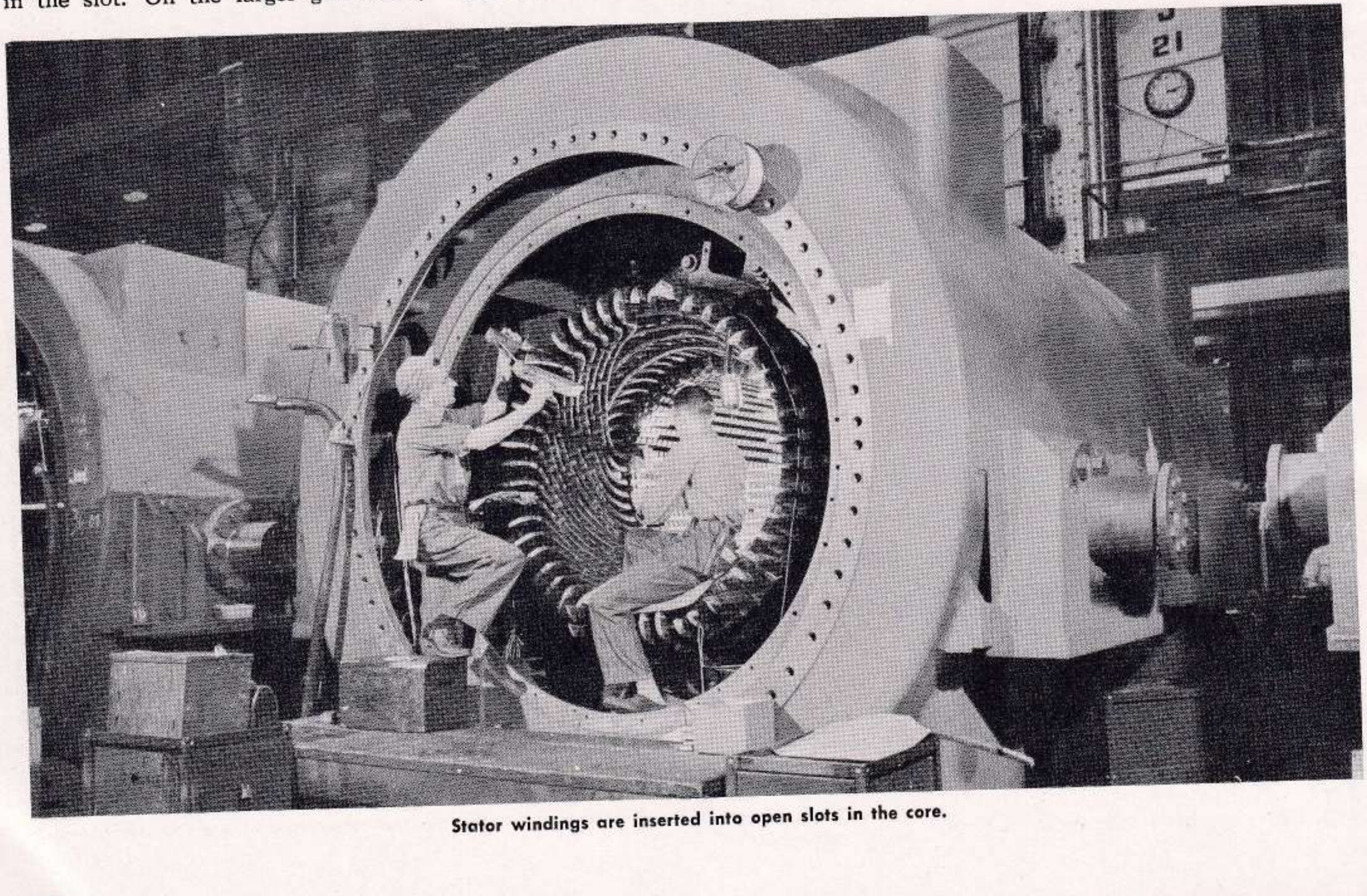
1. The copper for each bar is subdivided into small strands, each insulated from the others. This prevents overheating which might be caused by uneven distribution of the a-c current throughout the cross-section of the bar in the slot. On the larger generators, where this precaution alone would be inadequate, the strands within the bar are transposed. This completely neutralizes the effect of uneven current distribution in the slots.

2. The copper strands are covered with fiberglass or asbestos insulation and then carefully pressed into bars under heat and pressure.

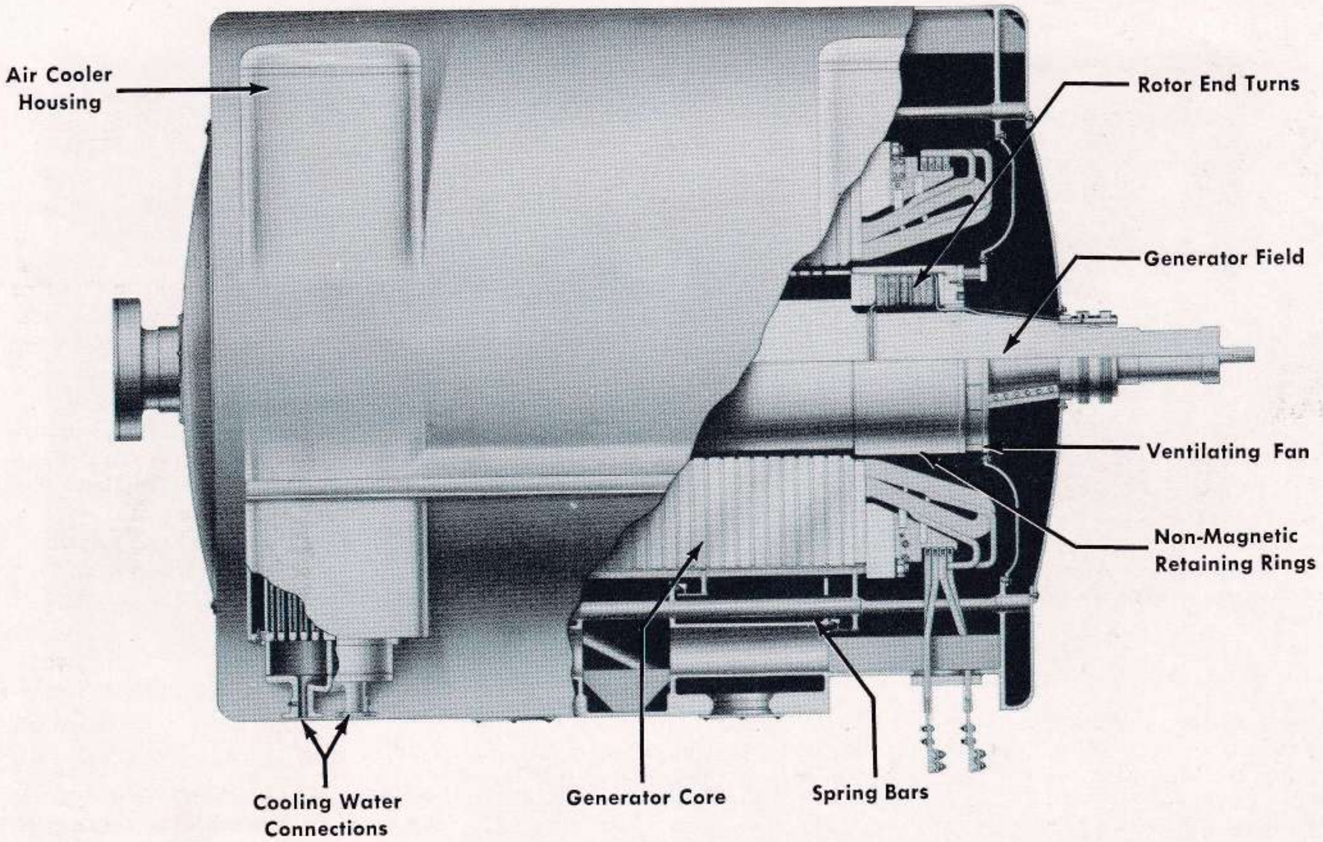
3. A low-voltage test is then made between each pair of strands to check against short circuits.

4. After the bars have been shaped for insertion in the stator, they are wrapped with high-grade mica insulating tape and treated under vacuum to remove all solvents and moisture.

5. The bars are then impregnated with a high-temperature asphalt compound which is applied under pressure to assure compactness and freedom from voids.



Stator windings are inserted into open slots in the core.



Cutaway view of air-cooled generator showing spring-mounted core.

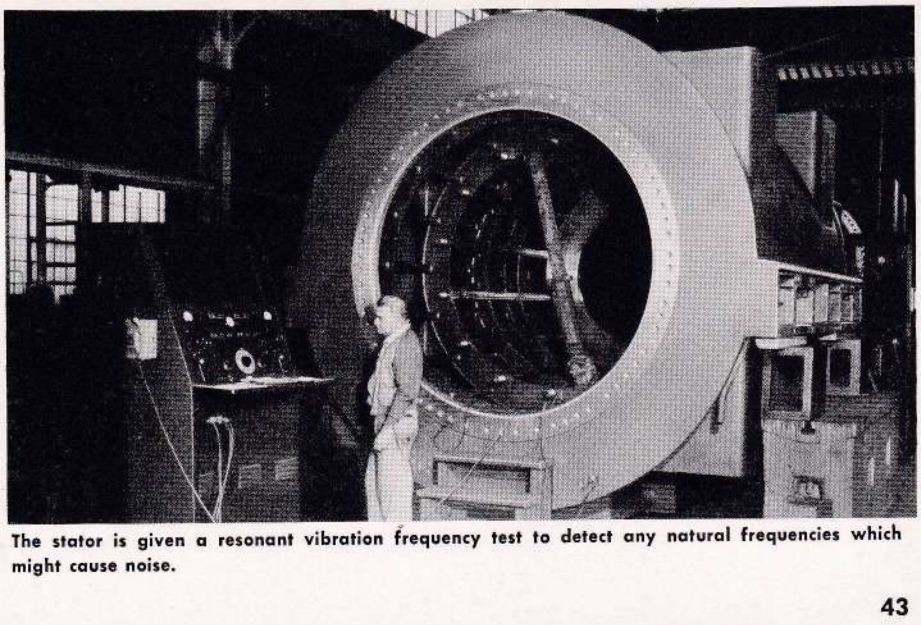
7. A SPRING-MOUNTED CORE IN A RIGID FRAME REDUCES NOISE AND VIBRATION

The generator frame, which supports the weight of the stator, is fabricated from high quality steel plates and bars. Individual sections of the frame are gas-cut from steel plate and arc-welded to a heavy, cylindrical, rolled-steel wrapper plate, to assure structure of great strength and rigidity. The wrapper plate itself forms the outer generator cover, so that no separate lagging plates are required. The enclosures for the four poster coolers are fabricated as an integral part of the frame. This maintains the rigidity of the structure.

When the generator is in operation, the enormous magnetic forces of the field poles tend to pull the stator core towards the center. Even though this deflection is only about two-thousandths of an inch, each point of the stator core is pulled in and released twice each revolution, setting up a vibration at a frequency of 120 cycles per second for 3600 rpm generators. To help prevent this double frequency from being transmitted to the frame and to the foundation, General Electric, on its medium and large size units, uses spring-mounting of the core to contain any vibration within the generator. The only connection between the stator core and the frame is through numerous flexible supports or spring bars, which are spaced circumferentially around the inside of the stator frame. This mounting is rigid in the direction parallel to the shaft but flexible in the radial and tangential directions.

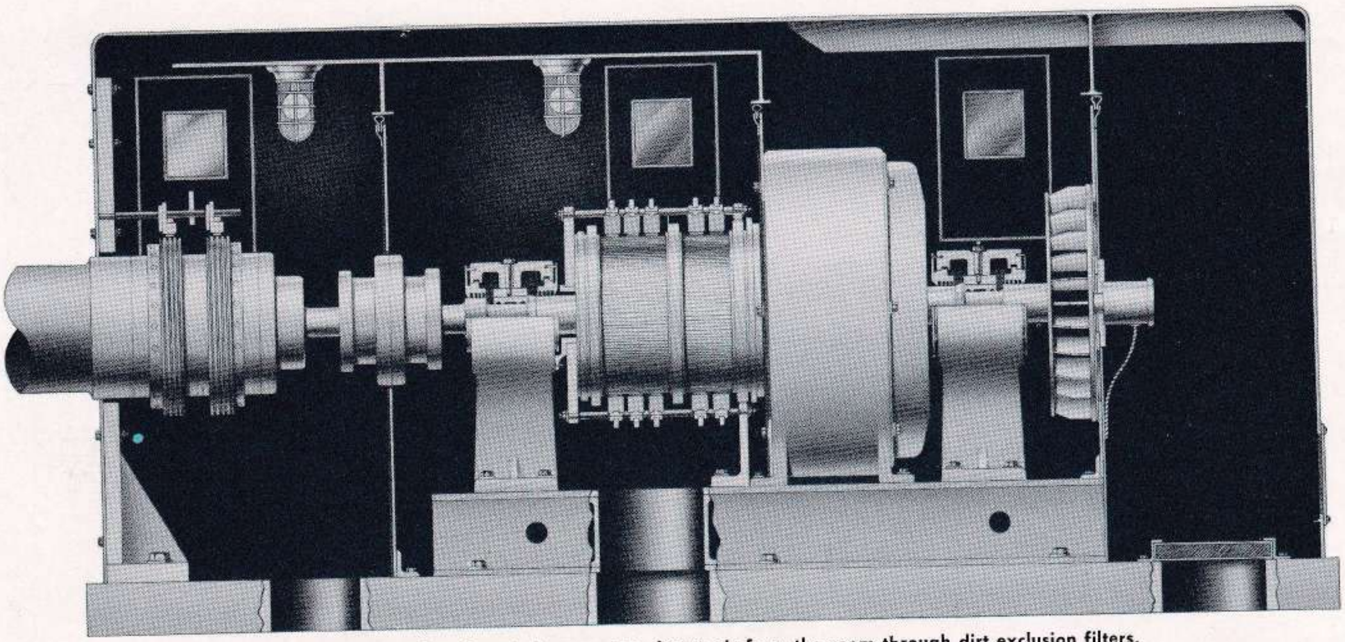
The spring-mounted core reduces noise by reducing vibration of the external parts. The integrally-cooled, totally-enclosed frame confines noise-producing inner elements. Other design features of the generator help prevent natural frequencies near 60 or 120 cycles per second. The external parts of the stator are "detuned" to decrease any external vibration or noise which might come from the generator.

Skillful designing, precise manufacturing, and careful testing are your assurance of a more reliable, efficient General Electric generator.



The stator is given a resonant vibration frequency test to detect any natural frequencies which might cause noise.

EXCITERS DESIGNED FOR TURBINE-GENERATOR SERVICE



This room-cooled exciter for air-cooled generators draws air from the room through dirt exclusion filters.

General Electric turbine-generator exciters are designed to provide a more reliable source of excitation with a minimum of maintenance expense.

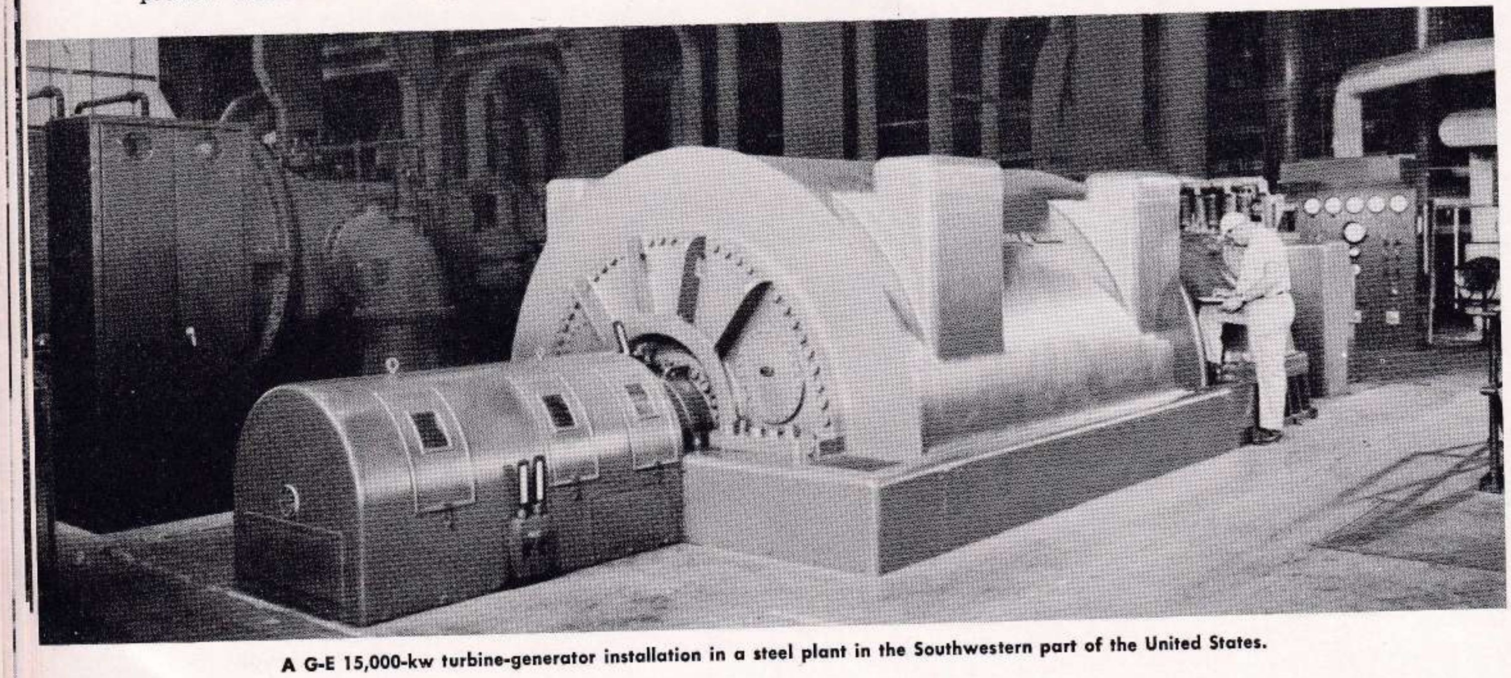
Each exciter is designed specifically for the unit of which it is a part. The exciter's electrical characteristics are such that its voltage will be stable down to a value below the minimum required by the generator. It can also be used with a generator voltage regulator.

The exciter is mounted on a shaft directly connected to the generator rotor through a flexible coupling which helps prevent transmission of any vibration from one shaft to another. The exciter and generator collector rings are totally enclosed in a specially designed housing.

The ventilation system is designed to help prevent contamination of the windings by dirt, oil, or carbon dust. A fan on the exciter shaft draws in room air through filters, thus excluding dirt. The discharge of the fan provides a positive pressure on the exciter bearings, reducing the possibility of oil vapor leakage. The flow of cooling air over the exciter is divided, with part passing through the windings and the remainder over the commutator. The air is then discharged into the room. The windings are kept free of carbon dust because none of the commutator cooling air passes over them.

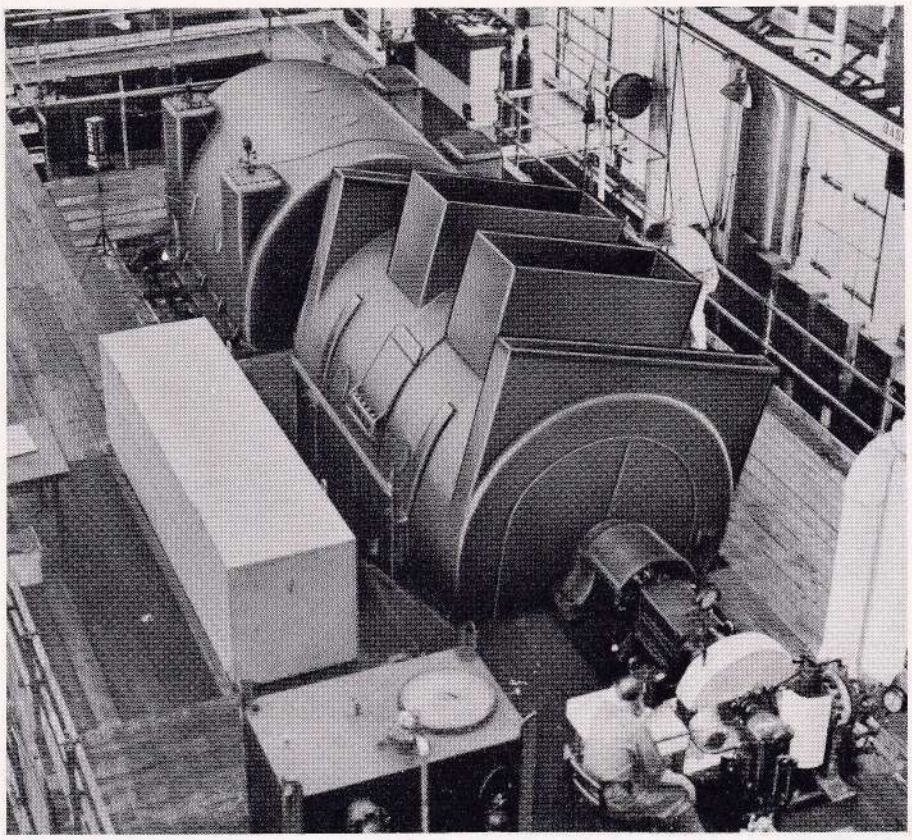
The housing is designed for convenience and easy accessibility. The light colored surface and interior lighting allow good visibility. The design of the housing doors provides ample room for any necessary adjustments.

After assembly the exciter is subjected to test runs to check mechanical balance, saturation curve, regulation and full load heat performance. It is then given a final insulation resistance measurement and high potential test.



A G-E 15,000-kw turbine-generator installation in a steel plant in the Southwestern part of the United States.

TURBINE-GENERATOR ASSEMBLY AND TEST



Generator being tested at full rated load and at various combinations of load and power factor.

To give each customer assurance of more reliable performance, all General Electric turbines and generators are subjected to exacting tests before shipment. All the rotating parts are designed with adequate margins of safety at 120 percent rated speed. The overspeed tests are run at 110 percent of rated speed.

The turbine is assembled at the factory and operated under steam for mechanical balance, checking of bearings, adjustment of the operating governor, adjustment of the overspeed governor and testing of the oil piping.

The generator is assembled at the factory on a special dynamometer test base and subjected to no load electrical and loss measurement tests. At the same time the rotor is balanced to minimize vibration.

The stator frame and other parts are subjected to vibration tests to eliminate any natural frequencies that might cause noise. New designs are given operating vibration and noise tests to maintain and improve these standards.

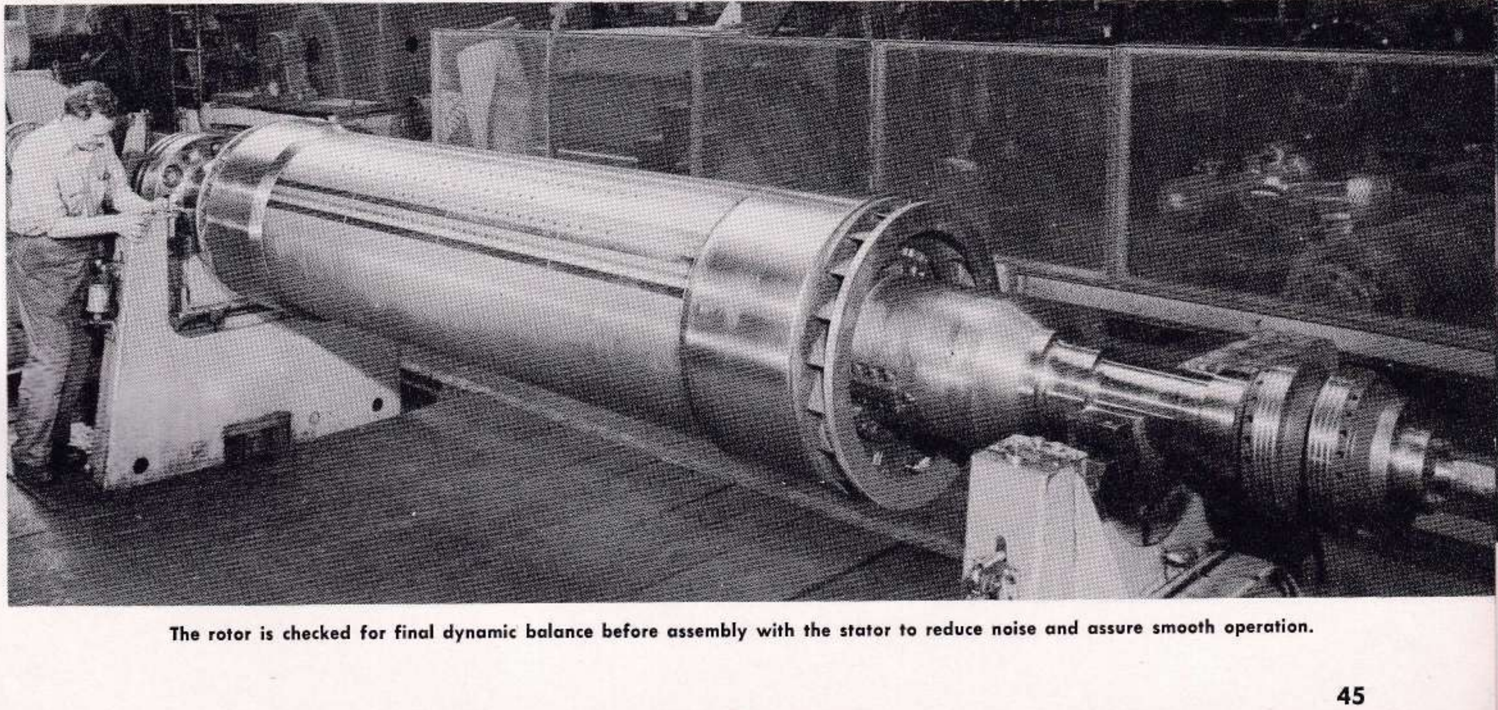
After undergoing a field seasoning run at 125 degrees centigrade and a 10 percent overspeed test the rotor is checked for final dynamic balance. Saturation and impedance curves are taken, and losses accurately measured with a dynamometer. Telephone interference factor, and voltage and current balance are checked. Then the generator is given another insulation resistance check and a final high potential test.

New designs and selected units are tested at full rated load, and at various combinations of load and power factor; such as from zero power factor lagging to zero power factor leading. These tests permit accurate evaluations of winding temperature rises under load, and of end heating and losses at various power factors.

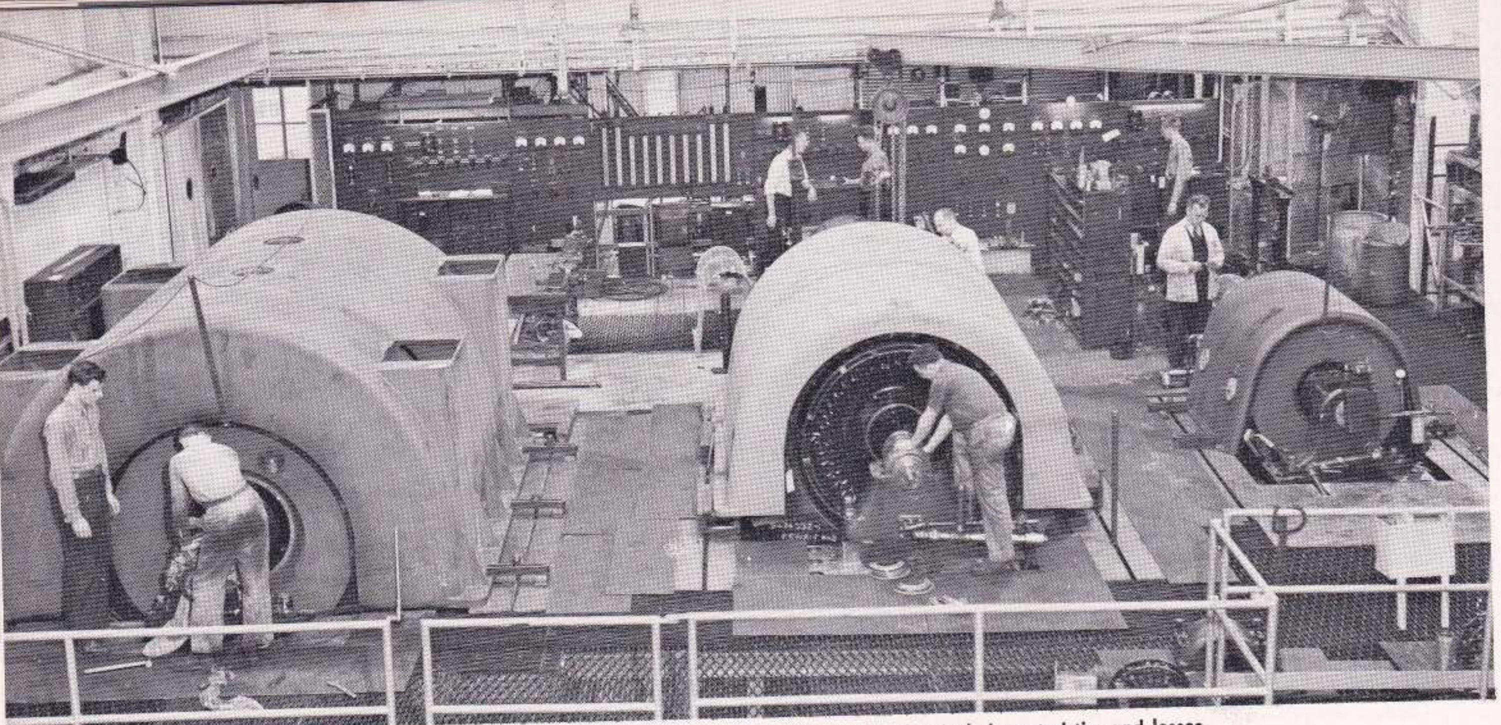
All these tests, both on the turbine and generator, must be approved by the Engineering Division before the unit is moved from test.

The exciter is assembled at the factory and tested for mechanical balance, saturation curve, regulation, resistance measurements, high potential, and full load heat run.

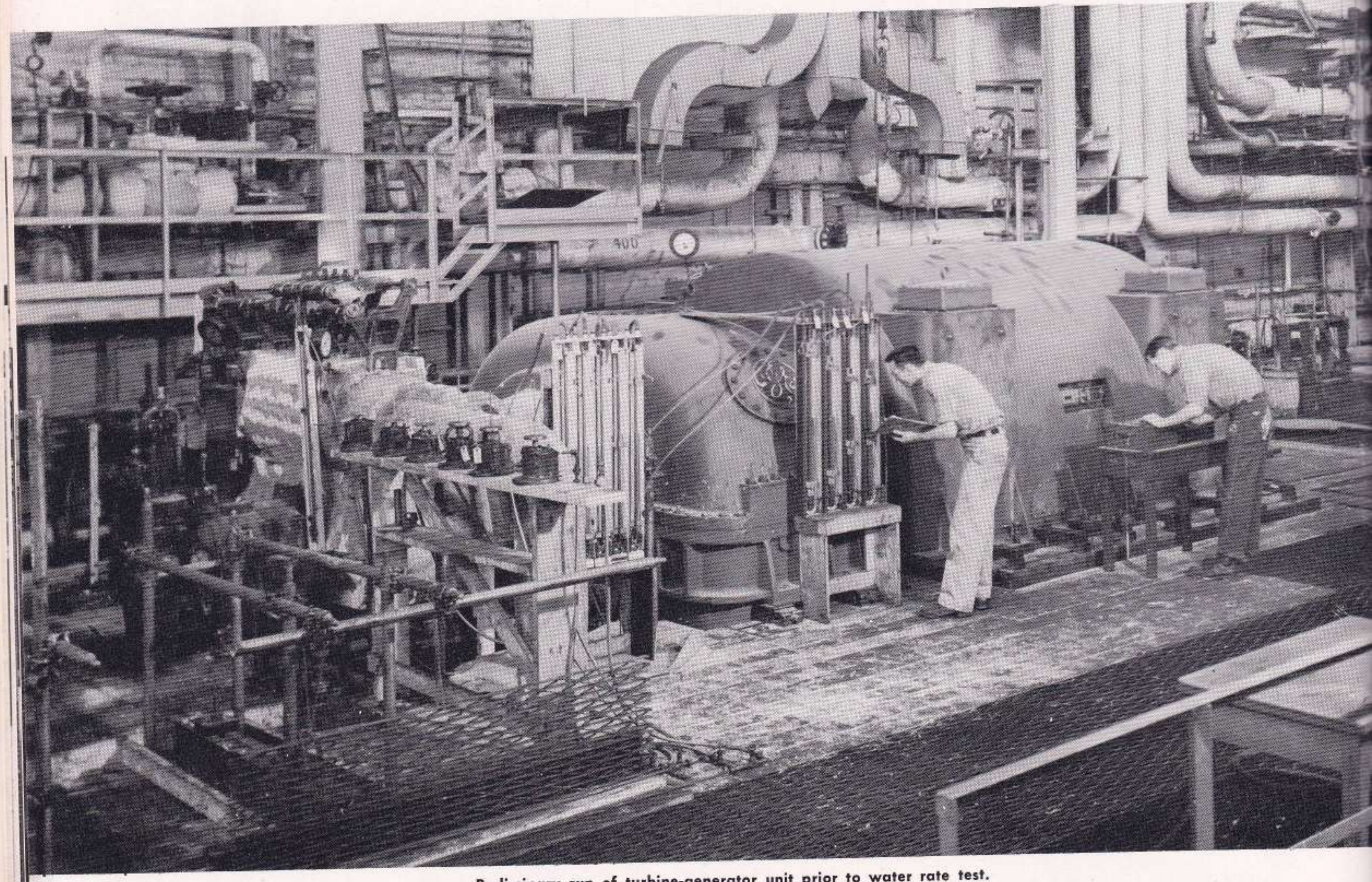
Such a testing procedure gives the greatest possible assurance of continuous more reliable service, low maintenance and long life. In addition, the testing process provides much valuable data which is continuously used to improve General Electric turbine-generator design.



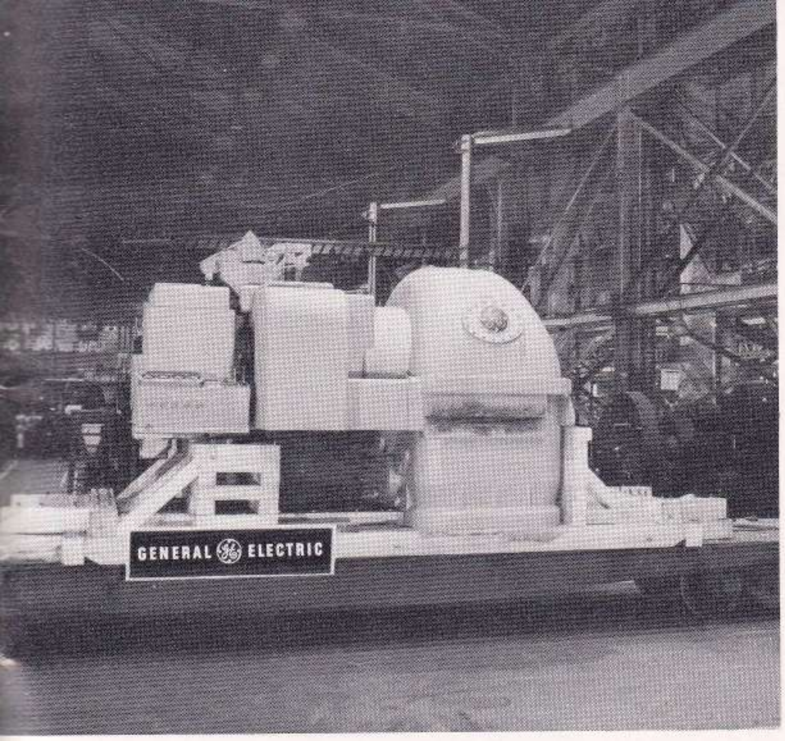
The rotor is checked for final dynamic balance before assembly with the stator to reduce noise and assure smooth operation.



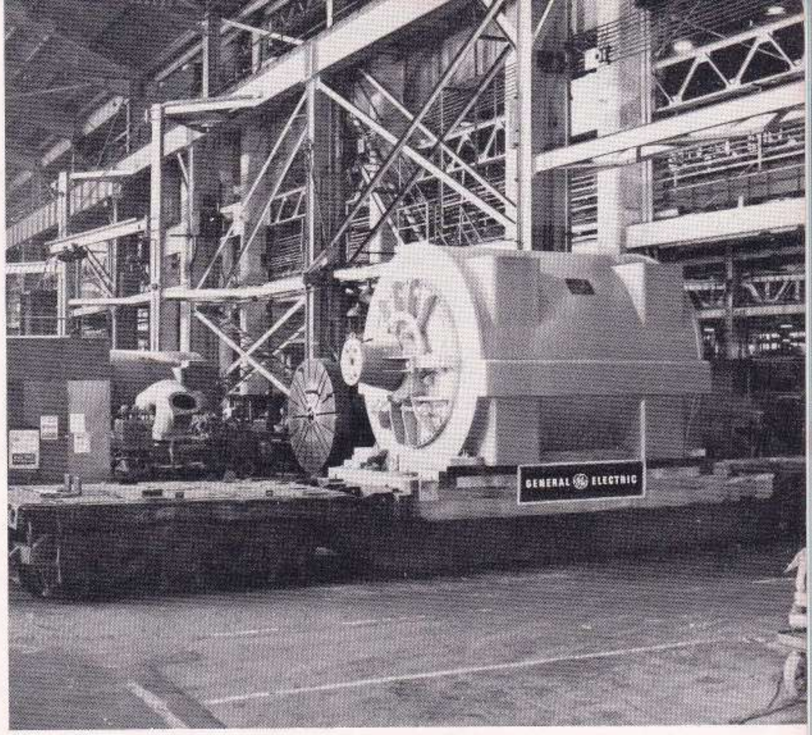
G-E generators are set up for a dynamometer test to determine electrical characteristics and losses.



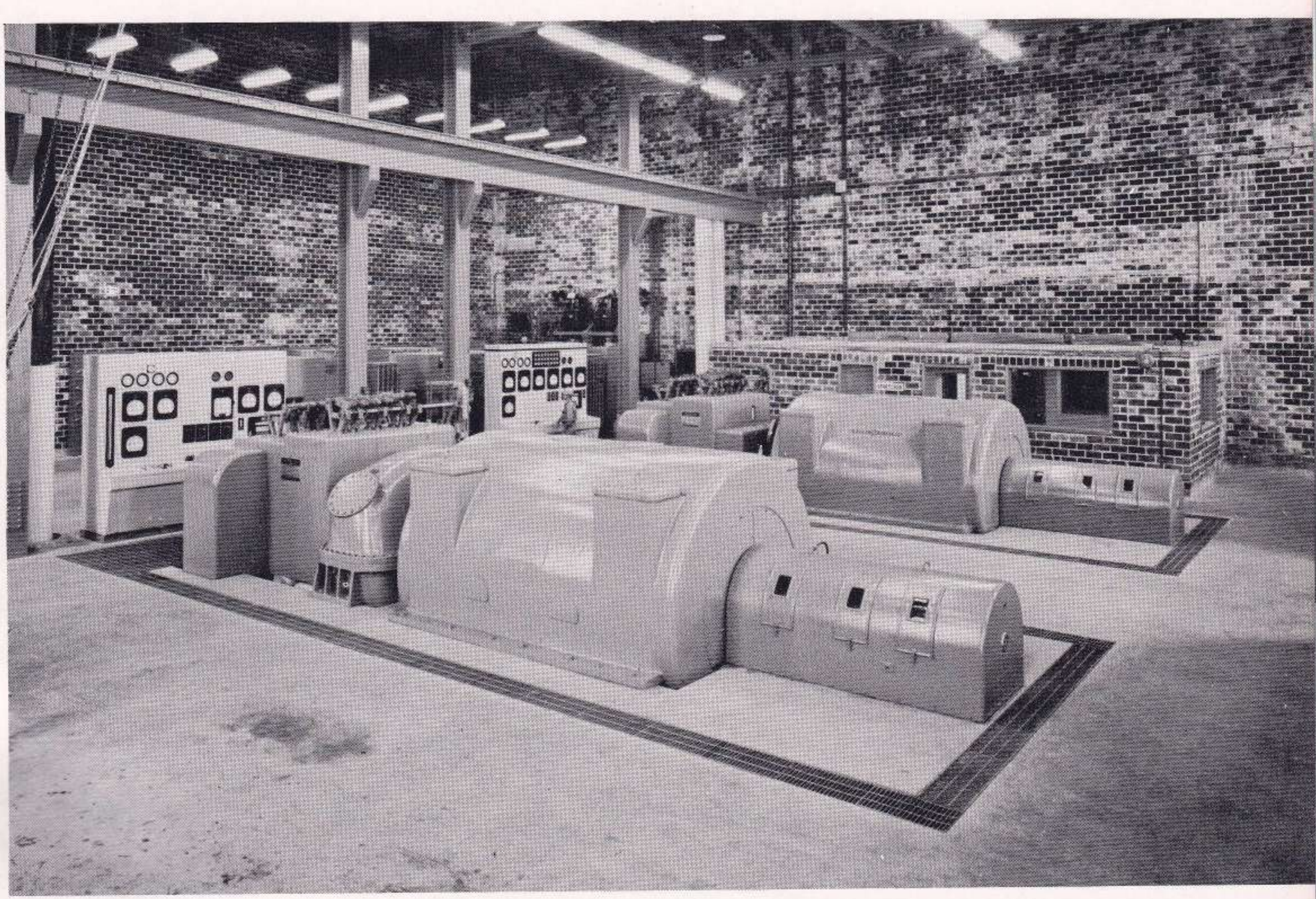
Preliminary run of turbine-generator unit prior to water rate test.



After all tests are completed the turbine is loaded onto a freight car for shipment to the customer's plant.



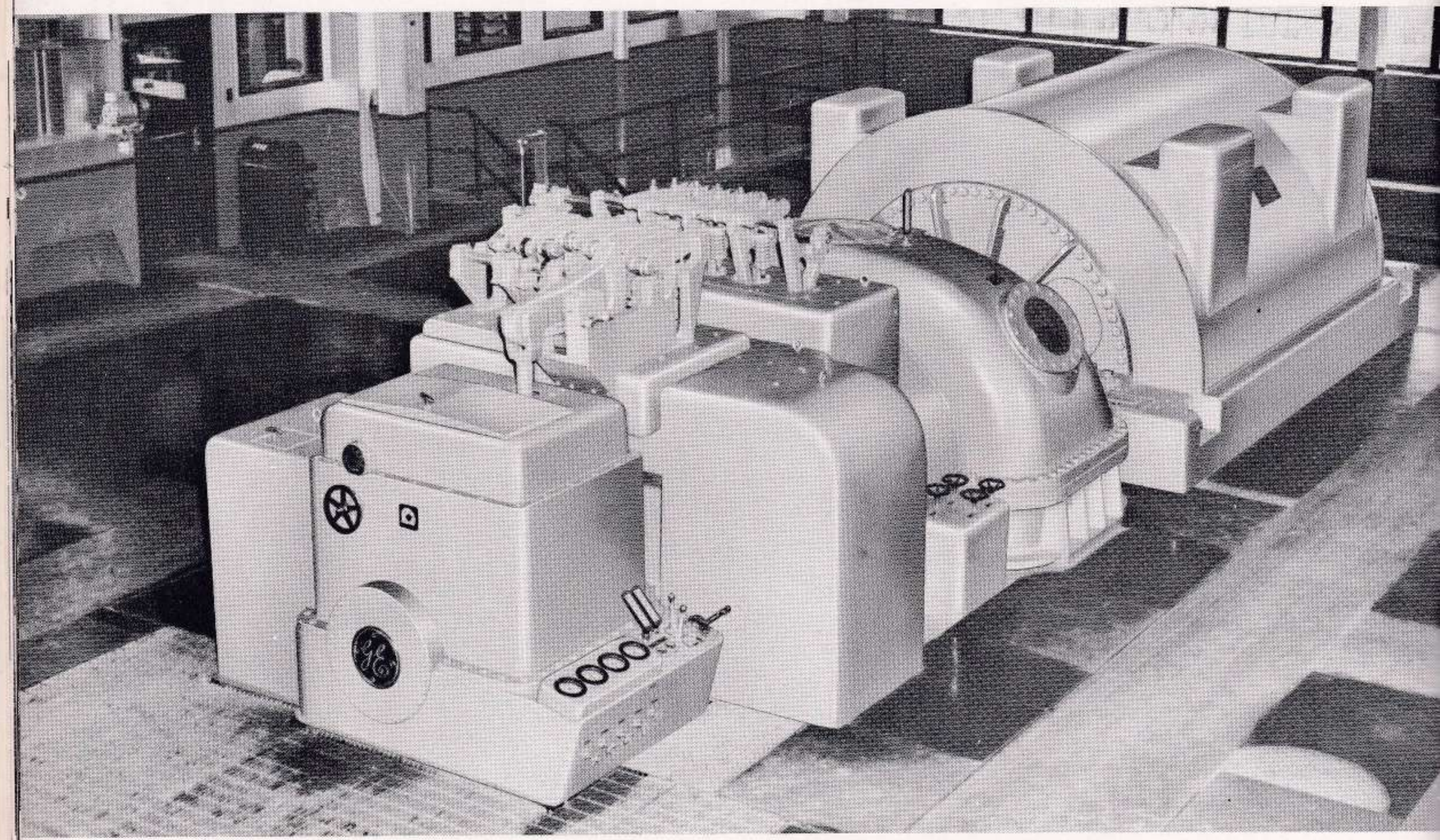
This hydrogen-cooled generator is being loaded onto a freight car for shipment to the customer.



Two 10,000-kw General Electric turbine-generators. You can be assured of expert installation and start-up service by General Electric's turbine engineers.

You Get More for Your Turbine Dollar with G-E Turbine-Generators because:

1. **Every component is carefully designed and manufactured.**
2. **Each unit is tested for more reliable, highly dependable performance.**
3. **Efficiency of impulse turbines stays higher during entire life of units.**
4. **You take advantage of General Electric's years of engineering and design leadership in the turbine-generator field.**
5. **You get assistance from G-E turbine engineers in selecting the best turbine for your needs.**
6. **You get installation service from G-E engineers and supervision of start-up of units.**
7. **Service Shops and Engineering Service are available if you need them.**



Careful manufacturing, designing and testing of units assure you of more for your turbine dollar with General Electric turbine-generators.

G-E APPARATUS SERVICE SHOPS AND ENGINEERING SERVICE . . . WHEN AND WHERE YOU NEED THEM

General Electric service engineers are ready to handle any problems concerning your steam turbine-generator installation which might arise.

Every turbine-generator built and sold by the General Electric Company is backed by the largest manufacturer of turbines in the world and by an outstanding service organization. The size and resources of this organization make it possible to give excellent service on machines in operation as well as engineering assistance on proposed installations.

General Electric has Managers of Turbine Installation and Field Service located in major cities throughout the United States. When maintenance attention is needed on your turbine-generator these expert General Electric engineers are prepared to help get your unit back into operation promptly. They are so located that they can reach almost any turbine installation in the United States in a day — usually in a few hours.

These turbine experts will answer any emergency call, analyze the problems and supervise any necessary repairs. They may also be able to suggest new methods and safeguards in maintenance which will cut costs and avoid future operating troubles. You can also call on your General Electric turbine engineer for assistance and advice on proposed installations.

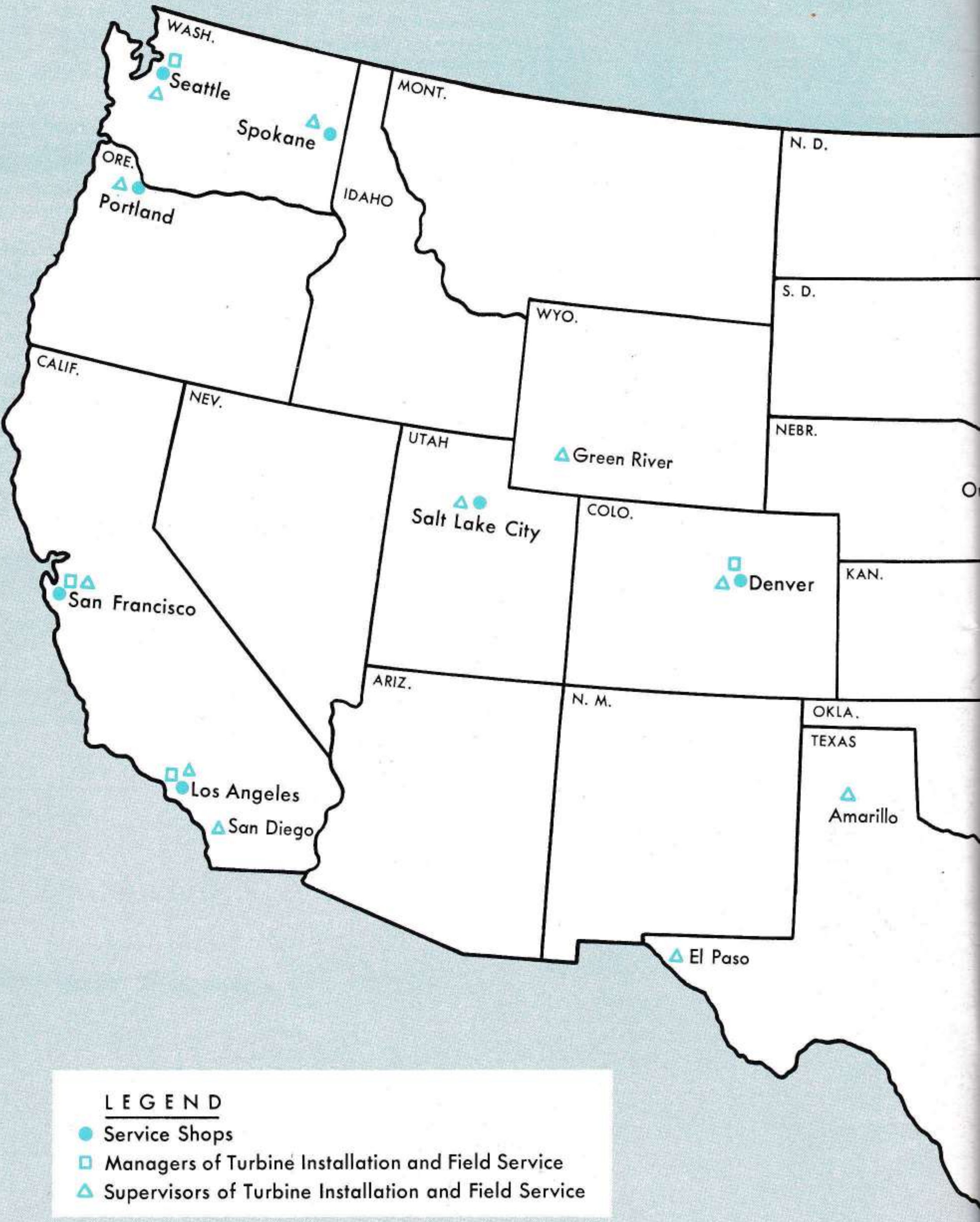
When the Manager of Turbine Installation and Field Service receives a call for help he has at his disposal a staff of turbine supervisors.

There are approximately 375 of these skilled supervisors located throughout the United States. The manager or supervisor also has the facilities of 32 General Electric service shops and the main manufacturing plants to back him. These shops are located from coast to coast and are staffed by expert factory-trained turbine craftsmen capable of handling any emergency — from minor repairs to complete turbine overhaul. Facilities of the service shops are available to you day and night, seven days a week. Work may be done on your premises or in the service shop.

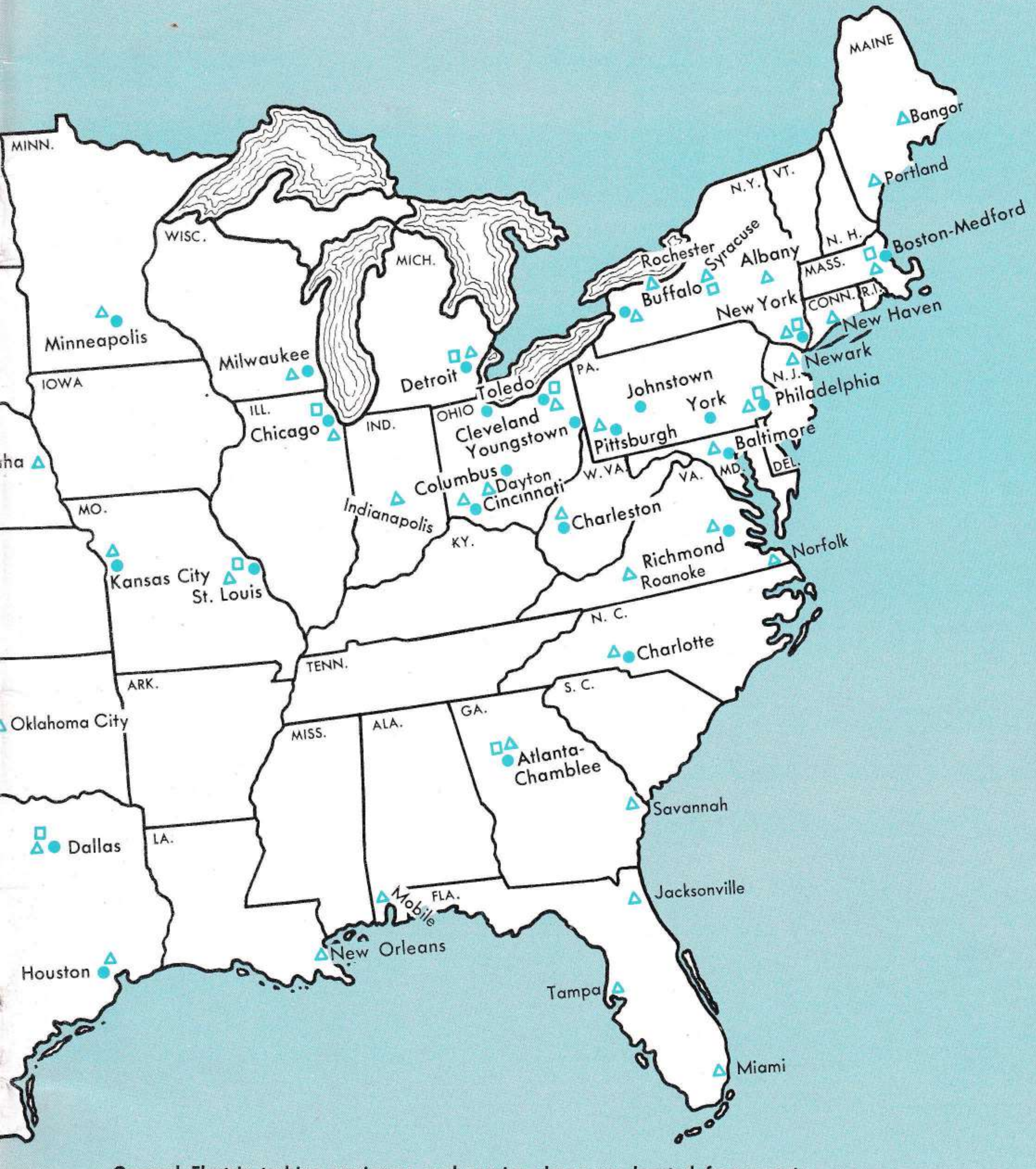
You can be assured of a minimum of shutdown time losses by calling on the facilities of this vast service system which are available to you with every General Electric steam turbine.

The General Electric service shop, as well as the factory, is prepared to give service on machines in operation.

14 MANAGERS AND 375 SUPERVISORS WITH

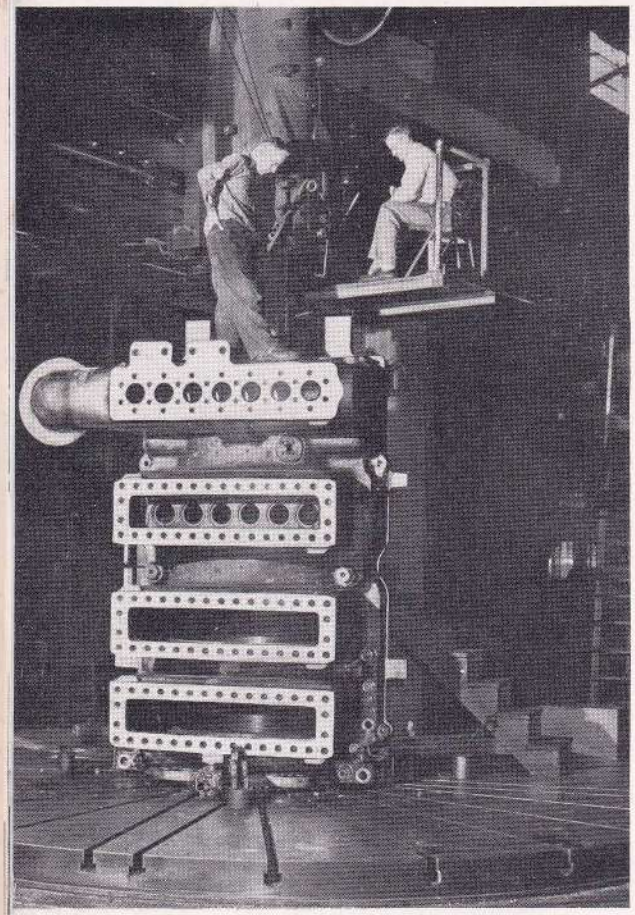


32 SERVICE SHOPS GIVE YOU COAST-TO-COAST SERVICE

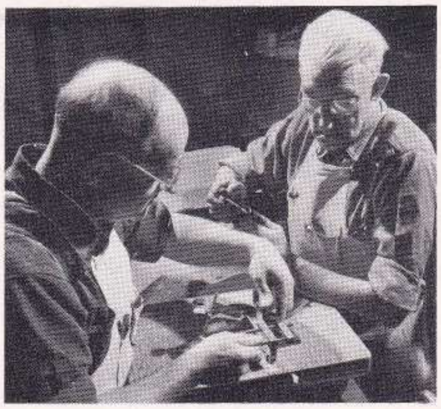


General Electric turbine engineers and service shops are located from coast-to-coast. They are available for immediate service on your turbine-generator.

Experienced Workmanship goes into Every Component of G-E Turbine-Generators

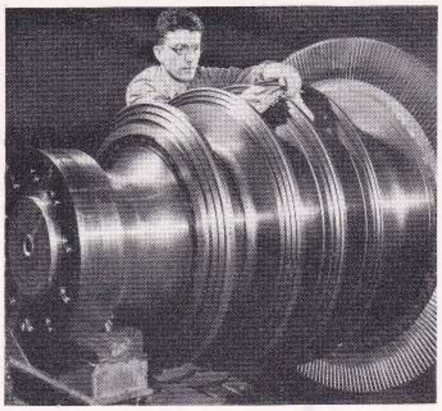


This casting of the first triple-automatic-extraction turbine is machined with powerful, precise equipment.



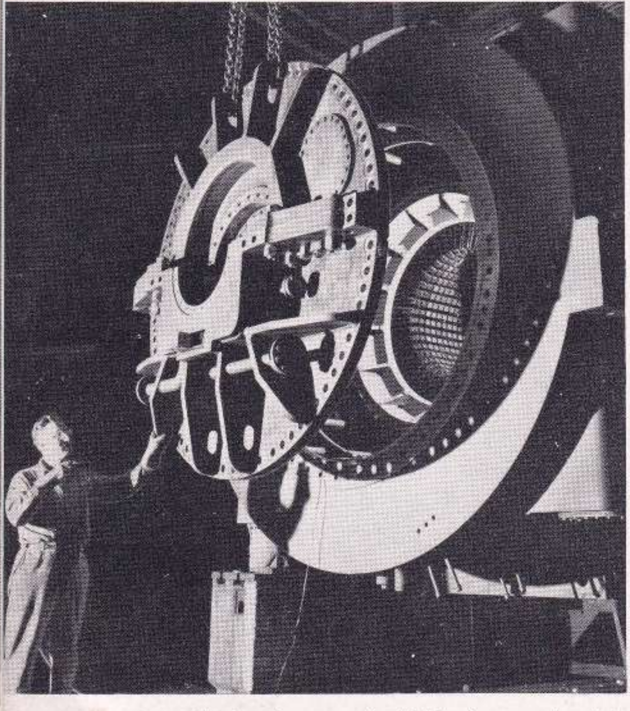
Skilled craftsmen work with precision instruments to assure maximum reliability of G-E turbine-generators.

G-E engineers work in a tradition of leadership. These men are discussing the turbine governing mechanism which appears behind them.

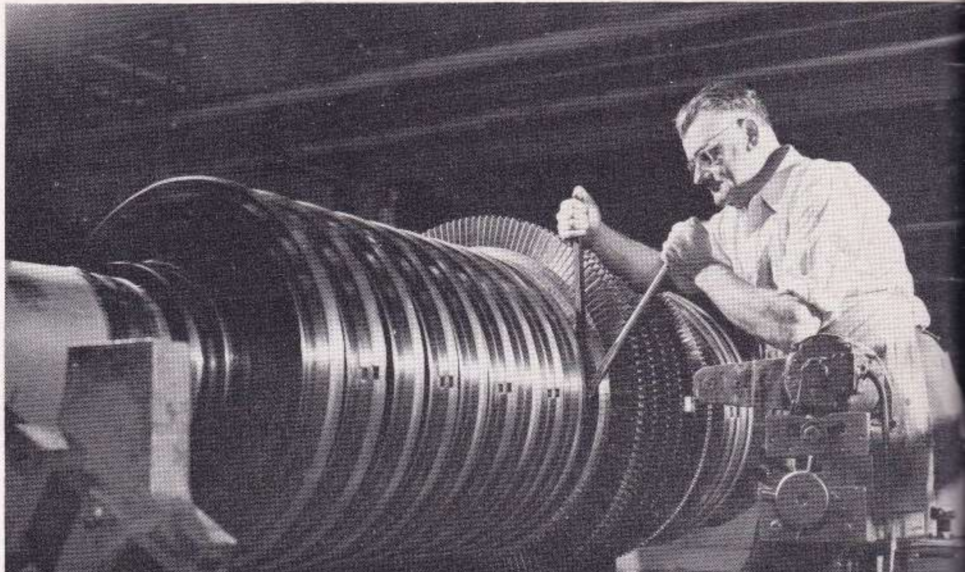


Continuous checks are made on rotor to assure maximum accuracy.

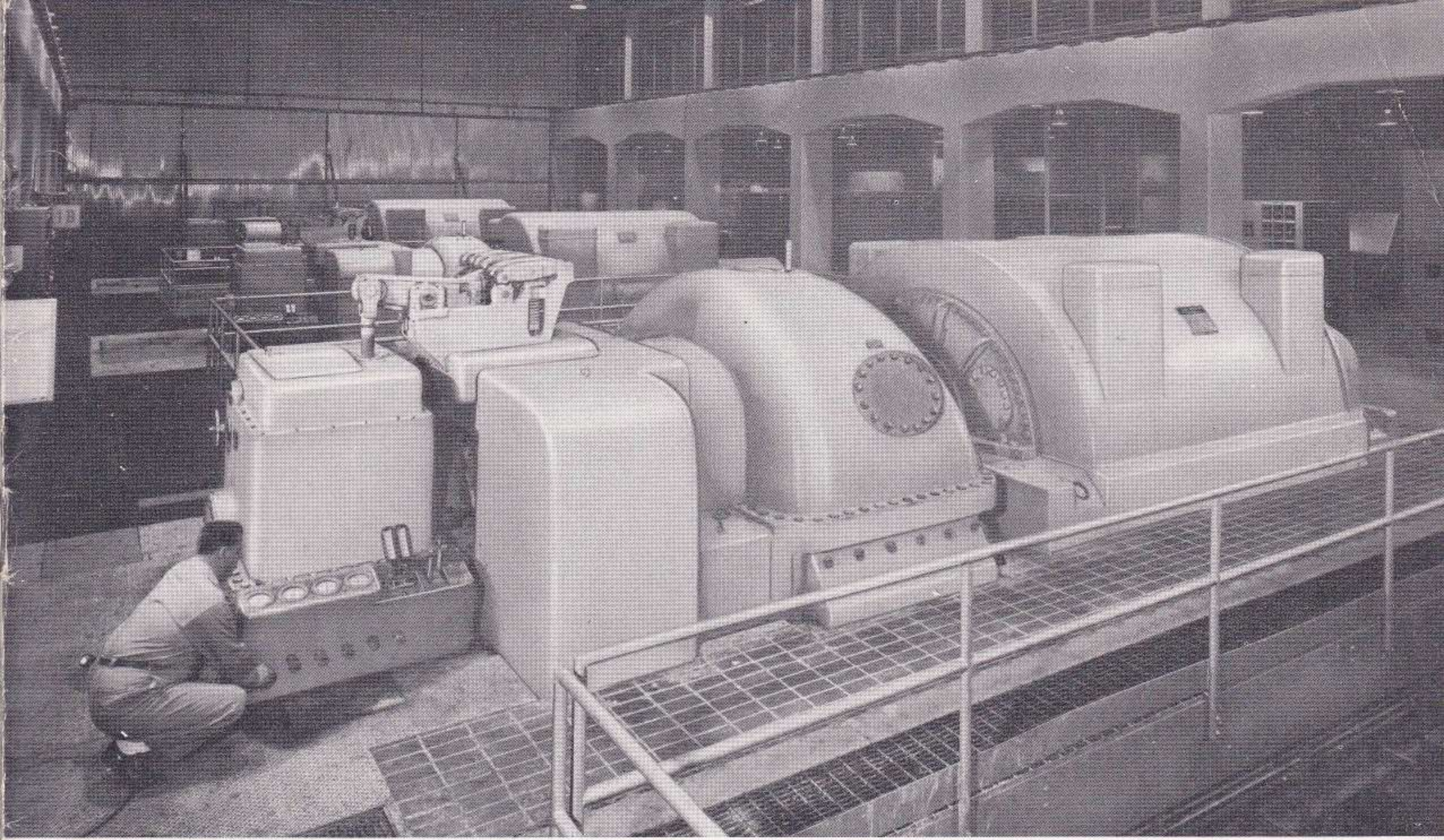
Bearings are given a final check — one of many tests to assure maximum dependability.



Moving heavy end shield of generator into position for assembly.

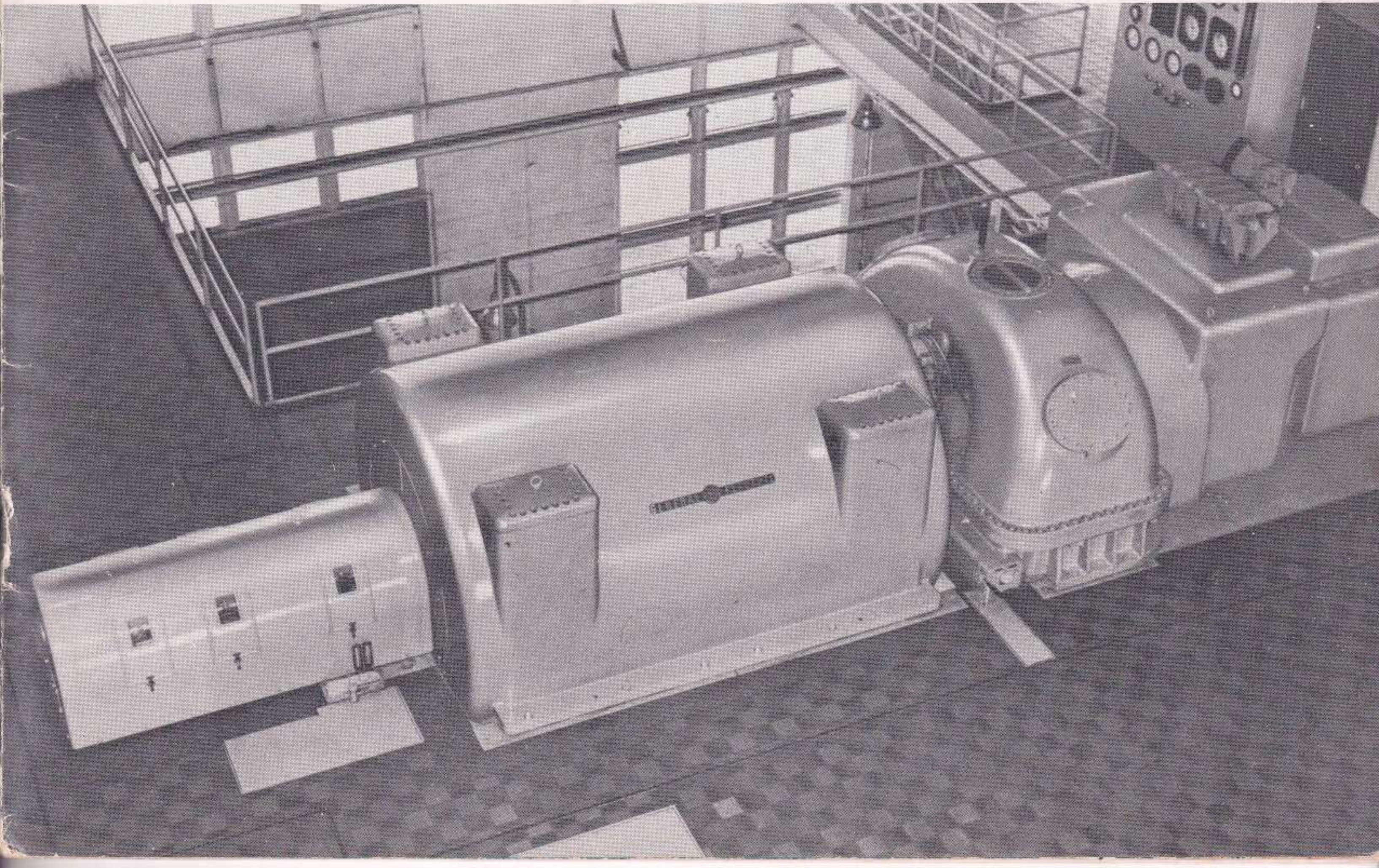


Turbine buckets are precisely assembled by craftsmen with many years of experience.



A service engineer makes final adjustments on a G-E turbine-generator in a modern aluminum factory. Two G-E turbines are in the background.

G-E turbine-generators bear evidence of the careful attention given to functional design and modern appearance as well as to operating efficiency and performance.



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